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14. ABSTRACT
RAND Project AIR FORCE (PAF) carries out a broad-based research agenda intended to help the Air Force enhance its abilities. This annual report contains summaries of our recent work.

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ANNUAL REPORT 2003

RAND PROJECT AIR FORCE

About RAND Project AIR FORCE

For more than 50 years, decisionmakers in the public and private sectors have turned to the RAND Corporation for objective analysis and effective solutions that address the challenges facing the nation and the world. The mission of RAND Project AIR FORCE (PAF), a division of the RAND Corporation and the Air Force's federally funded research and development center, is to conduct an integrated program of objective, independent analysis on issues of enduring concern to Air Force leaders. PAF addresses far-reaching and interrelated questions: What will be the role of air and space power in the future security environment? How should the force be modernized to meet changing operational demands? What should be the size and characteristics of the USAF workforce? How can that workforce be most effectively recruited, trained, and retained? How should sustainment, acquisition, and infrastructure be streamlined to control costs?

PAF carries out its research agenda in four programs that represent core competencies:

Strategy and Doctrine seeks to increase knowledge and understanding of geopolitical and other problems in the national security environment that affect Air Force operations. PAF maintains expertise in defense strategy; regional analysis; the objectives and tasks of evolving joint operations; and the potential contributions of air and space power to joint operations, defense planning, and requirements for force development.

Aerospace Force Development identifies and assesses ways in which technological advances and new operational concepts can improve the Air Force's ability to satisfy a range of future operational demands. This research involves assessments of technology feasibility, performance, cost, and risk. PAF assesses major force components needed in the future and the systems and infrastructure supporting their operations.

Manpower, Personnel, and Training concentrates on questions about workforce size and composition and about the best ways to recruit, train, pay, promote, and retain personnel. PAF's research encompasses the total workforce: active duty, guard, reserve, civilian, and contractor personnel.

Resource Management analyzes policies and practices in the areas of logistics and readiness; outsourcing, privatization, and contracting; the industrial base; planning, programming, and budgeting; infrastructure; and weapon-system

cost estimating. The goal of this program is to maximize the efficiency and effectiveness of Air Force operations in a resource-constrained environment.

PAF also conducts research on topics that cut across all four programs, and its research staff regularly responds to Air Force requests for help on time-urgent problems.

Director's Message

RAND Project AIR FORCE (PAF) carries out a broad-based research agenda intended to help the Air Force enhance its ability to rapidly strike the nation's enemies as well as to conduct a full range of peacekeeping, humanitarian, and other missions. This annual report contains summaries of our recent work. The results of several of these studies are highlighted below.

Counterterrorism and Other Contingency Operations Ever since the stunning attack of September 11, 2001, counterterrorism has been one of the principal concerns of the United States Air Force. PAF research indicates that, in the current security environment, the Air Force should expect sustained heavy demand to provide surveillance platforms, operators, and analysts; language-qualified personnel to help train and advise host-country forces and to analyze human intelligence; and security police and other force-protection assets.

In addition, small-scale operations can pose unique intelligence, surveillance, and reconnaissance (ISR) challenges because they often involve limited access to local bases; rough weather and terrain; and small, fast-moving targets. PAF studied several small-scale contingency scenarios to determine what ISR capabilities the Air Force requires to respond effectively under such constraints.

Analyzing data from deployments from 1996 through 2001, PAF also developed a method for reducing deployment times by balancing tradeoffs among materiel, personnel, and support services.

A Global Perspective The global nature of terrorism strongly underscores the need for the U.S. military to develop effective partnerships with allies and to operate in coalitions. The strengthening of the European Union has given the United States greater ability to engage with Europe as a whole rather than with its individual states. However, the United States must find the right balance between bilateral and multilateral approaches. Based on an analysis of diplomatic relations after September 11 and of the evolving roles of European institutions, PAF recommended that the United States pursue bilateral cooperation for military and intelligence matters and multilateral cooperation for financial and law enforcement matters.

In recent years, the United States has joined its NATO allies in air operations ranging from humanitarian relief to peacekeeping to major theater war. Yet interoperability remains an ongoing challenge. Differences in objectives, strategy, doctrine, communications, planning, and execution can slow and poten-

tially limit operational effectiveness. A long-term approach aimed at achieving flexible organizational structures, doctrines, and procedures is required to maximize the success of coalition efforts.

The November 2002 Prague summit represented an important step in NATO's evolution and approach to the East. By extending membership invitations to seven countries—Bulgaria, Estonia, Latvia, Lithuania, Romania, Slovakia, and Slovenia—NATO took a major step toward creating a "Europe whole and free." But while its Eastern agenda has been transformed, NATO still faces a range of important security challenges.

Modeling and Simulation PAF has both breadth and depth of expertise in the areas of modeling and simulation, particularly in the realm of warfighting simulation that is used to evaluate force structure. Simulations of key *processes* enable assessments of policy alternatives that improve both output effectiveness and cost. Such simulations are extremely important, both for their inherent value and because they underpin much of the higher-level analyses that PAF conducts. During this reporting period, PAF developed and applied "process models" that do the following:

- Enable analysts to predict future operational training needs for fighter squadrons. These models are being used to explore how organizational changes or greater use of flight simulators would affect training requirements.

- Calculate how maintenance requirements increase as aircraft age.

- Evaluate alternatives for providing intermediate maintenance of jet engines.

- Allow decisionmakers in three areas of the U.S. military—compensation, accessions, and personnel management—to achieve an integrated approach in analyzing and evaluating proposed changes in personnel policy for the enlisted force.

- Determine the appropriate amount of communications capacity to lease under conditions of uncertain demand.

- Improve the ability of analysts to validate models or data that reflect situations of great uncertainty rather than well-established theories or reliable data.

Broad Initiatives The Air Force Director of Supply asked PAF to look for ways to improve the Air Force logistics community's participation in the Air Force Planning, Programming, and Budgeting System (PPBS) process. Our research focused on depot-level reparable spares, which comprise a large portion of the total logistics budget and represent an area that offers many opportunities for improvement. We recommended strengthening the capabilities of the Air Force logistics community and involving logisticians more actively in planning and

budgeting. Complementary initiatives already underway may facilitate these changes, but the Air Force will have to address cultural factors that have prevented it from managing its logistics and supply chain activities more effectively.

As the executive agent for space within the Department of Defense, the Air Force must address several pressing military space issues. Our research reviewed the main milestones in the Air Force's involvement in space, explored the organizational and conceptual roadblocks that have impeded a more rapid growth of U.S. military space capability, and recommended steps that the Air Force should take to carry out its mandate.

Finally, PAF developed a broad conceptual framework designed to promote innovation and modernization within the Air Force and to help the Air Staff implement the "task force" approach created by the Air Force Chief of Staff. The framework defines a set of terms relevant to military capabilities and concepts of operation, identifies Air Force leaders responsible for guiding and promoting innovation, specifies a process to govern their interactions, and provides a list of operational capabilities that could be used to organize the efforts of the task force leaders.

Not discussed in this public-domain report is PAF's research on developing concepts for long-range strike, denying sanctuary to adversaries, determining a future regional posture for Pacific Air Forces, integrating unmanned combat aerial vehicles into global-strike concepts of operations, and analyzing alternatives for the next-generation gunship. However, these studies—along with the ones described above—are all part of a coherent and comprehensive program of research that is reviewed and approved annually by our oversight body, the Air Force Steering Group.

PAF represents an ongoing Air Force investment in objective research and analysis. This close collaboration, now nearly six decades long, provides us with the necessary flexibility and continuity to explore issues of vital importance to the nation's security and to apply insights gained from past research to the Air Force's current and future needs.

Natalie W. Crawford
Vice President, RAND Corporation,
and Director, RAND Project AIR FORCE

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Publications

Administration

Counterterrorism Operations Abroad: Estimating Future Demands on the United States Air Force

The September 11, 2001, terrorist attacks on the United States provided a stunning demonstration of America's vulnerability to attack by a small group of determined fanatics. Indeed, modern technology and its dispersion are placing increasingly destructive instruments at the disposal of growing numbers of people. As long as such groups believe they must use violence against Americans and American interests, we will be vulnerable to the threat of terrorist attack.

The imperative to monitor, suppress, attack, and ultimately eradicate international terrorist groups seeking to strike the United States, its citizens, its interests, and its allies is prompting significant changes in the demands placed on the armed forces of the United States. The initial phases of the war on terrorism—such as Operation Enduring Freedom in Afghanistan and Operation Iraqi Freedom—involved conventional combat operations against regimes that supported terrorist groups. Increasingly, however, U.S. military forces will need to fight al Qaeda and other groups in countries that do not support terrorism but are too weak militarily or politically to counter such groups on their own. U.S. operations in these countries will look less like traditional warfare and more like what has been called "nation assistance," "foreign internal defense," and counterinsurgency.

Is it possible to generalize about the demands of counterterrorist operations? As part of a larger study to think strategically about combating terrorism, RAND Project AIR FORCE (PAF) studied effective counterinsurgency operations to derive concepts for likely U.S. strategy against terrorist groups abroad.

The research focused on the types of overseas operations that U.S. military forces will likely employ in an attempt to eliminate or weaken terrorist groups—a key element of the "offensive" portion of the national counterterrorist strategy. Those operations will be shaped, in the first instance, by the political setting in which the targeted groups are operating. Countries of concern span a wide gamut, from traditional security partners, such as the Philippines, to states with which the United States lacks a long history of security cooperation, such as Yemen. Some, like the governments of Uzbekistan and the Philippines, seek to prosecute fairly aggressive operations against ter-

rorist groups on their territory. Others, such as Sudan, Indonesia, and Somalia, may have a more ambivalent attitude or simply be incapable of mounting effective operations.

Figure 1 provides a means for sorting among states according to two criteria: the degree to which each state opposes the existence and operations of a particular terrorist group and the degree to which each state is capable of countering that group within its borders. The resulting categorization highlights the differences in strategy that the United States and its armed forces will use in countering terrorist threats.

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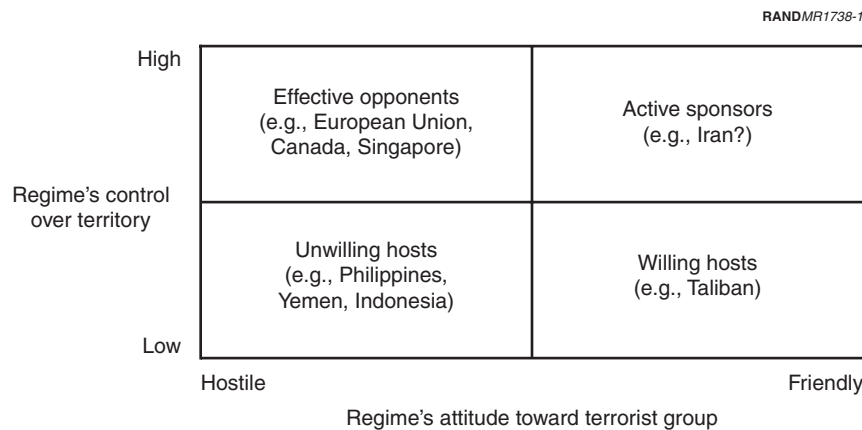
Figure 1—U.S. Strategy and Operations Are Shaped by the Nature of the Regime and the Threat

PAF Defined the Principal Elements of a Generic Operational Strategy

Despite the fact that the nature of military operations against terrorist groups will vary widely depending on the circumstances in each country and situation, planners need some sort of conceptual model to prepare forces and develop capabilities. Combatant commanders charged with devising and implementing operations to weaken or eliminate terrorist groups operating abroad will generally pursue some or all the following operational objectives defined by PAF:

- Strengthen the capabilities and will of host-government forces.
- Disrupt the activities of terrorists—e.g., prevent or disrupt recruitment and training, disrupt communications and databases, intercept the movement of critical materiel and personnel, and protect potential targets.
- Help to alienate terrorists from the populace.
- Gather intelligence about terrorist networks and activities around the world.
- Protect friendly forces and bases.
- Prevent terrorists from acquiring, retaining, or using chemical, biological, radiological, or nuclear weapons.
- Find and capture or kill terrorists.

The last of these objectives may become more difficult over time because terrorists who survive efforts aimed at their destruction will adapt by presenting ever-smaller "signatures" that might be used to locate and identify them. Accordingly, improvements are called for in the capabilities of U.S. air forces to locate, identify, and attack very small groups of people or individuals with the appropriate level of confidence that the right target is being attacked and that innocent civilians will not be placed at undue risk. Innovations in wide-area surveillance, high-resolution sensors, and precise weaponry, as well as accurate communication between the "finders" of the proper targets and the "shooters" of the target will be critical.

Given the generic operational objectives, effective counterterrorist efforts, especially in "willing but weak" states should be based on the following principles:

- Host governments, not the United States, should play the leading role in hunting down terrorists.
- Terrorists should be subjected to relentless pressure by host government forces so that they cannot determine the tempo and timing of operations.
- Effective counterterrorist operations will be "information intensive," relying on accurate information about the activities, locations, and identities of terrorists.
- Most important, host governments should seek to win the support of their populations, thus alienating terrorists from potential sources of support.

Counterterrorism Will Require a Mix of Air Force Capabilities and Long-Term, Sustained Effort

The war on terrorism is more likely to be a long-term effort in which the use of force, at least by U.S. military personnel, is only sporadic and successful military operations will resemble counterinsurgency operations. The primary role of U.S. military forces will often be indirect and supportive. U.S. forces will be called upon to train, equip, advise, and assist host-country forces in rooting out terrorist groups; forge strong relationships with host-country personnel; show great discretion in their conduct of operations; and maintain a low profile in the host country. They will be able to react swiftly and effectively when promising targets arise.

The Air Force, then, should expect sustained heavy demand to provide important capabilities, assets, and skill sets to support counterterrorism operations abroad. Chief contributions will include surveillance platforms, operators, and analysts; language-qualified personnel to help train and advise host-country forces and to analyze human intelligence; security police and other force-protection assets; base operating support personnel and equipment to provide communications, housing, and transportation; heliborne insertion and extraction capabilities; and humanitarian relief assets. In some cases, U.S. airpower may be called upon to strike terrorists in base camps, hideouts, vehicles, and other locations.

Dimensions of U.S. Involvement in Selected Counterterrorist Operations

Table 1 summarizes these findings. The columns include the major types of roles that U.S. military forces might play in countering terrorist groups and activities abroad, and the rows show PAF's judgments regarding roles that are likely to be called for in specific cases—some actual and some potential. Table 1 suggests that large-scale operations (such as Enduring Freedom in Afghanistan after September 11, 2001) that involve U.S. forces in the full range of counterterrorist activities, including combat, are likely to be few and far between. On the other hand, the Air Force and the other military services can expect widespread and sustained demand for forces and assets capable of gathering information about terrorist operations, assisting friendly

forces (at least indirectly) in the conduct of counterterrorist operations, training and advising those forces, and protecting U.S. forces and bases abroad from attack.

Table 1—Dimensions of U.S. Involvement in Selected Counterterrorist Operations

Country	Target Group	Probable Numbers of Terrorists	Roles of USAF Forces							
			Collect Intelligence	Train/ Advise	Assist During Operations	Strike	Civil Affairs	Combat Search and Rescue	Psycho-logical Operations	Force Protection
Afghanistan (post Taliban)	al Qaeda, Taliban	1,000+	√	√	√	√	√	√	√	√
Pakistan	al Qaeda, Taliban	Hundreds	√		?					√
Philippines	Abu Sayyaf	100–200	√	√	√		√	√	?	√
Yemen	Islamic Army of Aden, Yemen Islamic Jihad	Several hundred	√	√	?	?	?	?		√
Uzbekistan/ Fergana Valley	Islamic Movement of Uzbekistan	Hundreds	√	?	√					√
Somalia	Al Ittibad Al Islamiya	-1,000	√	?	?	√	√	√	?	√

Note: "Assist during operations" includes intelligence, planning, communications, tactical mobility, and/or airborne fire support.

MR-1738-AF, *Military Operations Against Terrorist Groups Abroad: Implications for the United States Air Force*, David A. Ochmanek

Counterterror Coalitions:
How Should the United States Engage Europe?

The September 11, 2001, terrorist attacks on the United States were widely interpreted in Europe as a broader attack on Western values. As a result, leaders from nations throughout Europe pledged their willingness to cooperate in counterterror efforts; and, for the first time in history, the North Atlantic Treaty Organization (NATO) invoked its Article 5 collective defense provision. These events called into question the U.S. preference for bilateral relationships with allies.

The strengthening of the European Union (EU) has given the United States greater ability to engage with Europe as a whole rather than with its individual states. However, the United States must find the right balance between bilateral and multilateral approaches. Based on an analysis of diplomatic relations after September 11 and of the evolving roles of European institutions, PAF recommends that the United States pursue bilateral cooperation for military and intelligence matters and multilateral cooperation for financial and law enforcement matters.

Recent Operations Highlight the Drawbacks of Multilateral Military Cooperation

After NATO invoked its self-defense clause on September 12, 2001, U.S. policymakers had to decide how to engage the alliance in the military campaign in Afghanistan. Despite the close ties between NATO's members, the United States saw the organization as unable to provide a strong command structure for military action. The 1999 NATO-led war in Kosovo had shown the alliance's inability to conduct a quick and decisive campaign. Many U.S. policymakers viewed the Kosovo war as an example of an ineffective "war by committee" and they did not want to repeat it. In the response to September 11, the United States chose to use NATO forces to backfill U.S. assets instead of giving NATO a primary role in the effort.

In addition to the collective support through NATO, European states individually offered military support to Operation Enduring Freedom in Afghanistan. The United Kingdom and France contributed a wide array of forces, and many other countries provided smaller contingents. European countries on both

sides of the continent also provided crucial basing, access, and overflight rights. Throughout the operation, U.S. policymakers were determined to retain sole command authority, and they refrained from giving NATO a more prominent role.

When U.S. attention shifted from Afghanistan to Iraq, debates arose within the alliance about whether Iraq should be the next target in the war on terror. In January 2003, the United States officially asked NATO to contribute to the campaign against Iraq. France, Germany, and Belgium opposed the action; others agreed. Because the NATO members could not reach consensus, the United States elected to collaborate with willing allies outside of the NATO framework. NATO itself was torn by disagreements over its role and the next steps in the war on terror.

The EU Offers a Strengthened Network of Judicial and Law Enforcement Capabilities

An unexpected outcome of the September 11 attacks was to encourage further integration within the EU, particularly in law enforcement and finance. EU members realized that common police and judicial efforts would be crucial to identifying terrorists located within their borders. Therefore, they worked together to revitalize the EU's Directorate of Justice and Home Affairs. Through the Directorate, the EU made a number of important initiatives, including adopting a common arrest warrant, increasing the role of Europol, strengthening Eurojust, and combating terrorist financing.

These measures represent important steps toward the establishment of a single judicial area and a coordinated law enforcement network. The EU is also taking action to require all of its members to harmonize their positions on money laundering, asset freezing, and methods of combating terrorist financing. Since September 11, the EU has been actively engaged in initiatives designed to counter terrorism through legal and financial methods.

The United States Must Strike a Balance Between Bilateral and Multilateral Approaches

Countering terrorism is an inherently challenging task that requires deep and sustained international cooperation across a wide range of issues. NATO's small role in Operation Enduring Freedom demonstrates that multilateral

cooperation is not essential in U.S. military actions. Given NATO's reluctance to embrace counterterrorism as a new mission and the EU's lack of military centralization, the United States will likely find it necessary to continue bilateral cooperation for military and intelligence matters. However, multilateral relationships will become increasingly significant in financial and law enforcement cooperation as the EU continues to expand intra-European cooperation in Justice and Home Affairs. The United States will need to adapt its approach to counterterror coalitions as European institutions continue to evolve.

MR-1746-AF, *The Counterterror Coalitions: Cooperation with Europe, NATO, and the European Union*, Nora Bensahel

Interoperability of Coalition Air Forces: Lessons Learned from U.S. Operations with NATO Allies

In recent years, the United States has partnered with NATO allies in a large number of air operations, ranging from humanitarian relief and peacekeeping missions to major theater war. Interoperability—the ability of military forces from different countries to work effectively together—poses an ongoing challenge. Differences in objectives, strategy, and doctrine; incompatible communications; diverse planning and execution systems; and dissimilar weapon systems all can slow operations and threaten to limit effectiveness. In the past, NATO allies have addressed interoperability problems by developing short-term and usually incomplete solutions on an ad hoc basis. A long-term approach is needed to prevent the most common interoperability problems from occurring in the future.

PAF studied recent coalition air operations in Southwest Asia, the Balkans, and Africa to derive lessons for improving NATO interoperability.

- *Interoperability problems may occur at all levels of warfare—strategic, operational, tactical, and technological.* Military planners tend to think of interoperability as a technical and tactical concern. However, interoperability may also be affected by disagreement over the political objectives of a military operation, such as whether to pursue total destruction of an adversary or some agreed-upon level of damage to his forces. Problems at one level can affect interoperability at other levels. For example, the absence of secure communication among allies can increase the risk of aircraft attrition. This problem can exacerbate political differences over the number of acceptable casualties.

- *Allies must recognize and address the fundamental sources of interoperability problems.* In cases where political motives are misaligned, no amount of technological improvement will mitigate the problem. For example, in Somalia, disagreement among allies over the purpose of the mission led to a chain of command that proved incapable of preventing or mitigating the consequences of a downed helicopter. Consensus at the strategic and operational levels will make tactical and technical problems less likely and easier to resolve when they arise.

- *Successful operations require flexible organizational structures, doctrines, and procedures.* NATO allies often face uncertainty about what missions will be needed, which countries will participate, and what types of forces each country will contribute. Potential disruptions in interoperability can be mitigated through a unified command structure to coordinate the roles of various countries. Standing organizations devoted to planning, training, and exercising coalition forces can provide continuity between operations. These elements should be enhanced by the ready availability of liaison officers to overcome cultural and linguistic barriers and to facilitate information flow between allies.

These case studies have supported PAF work to improve U.S.–NATO interoperability in the areas of command, control, communications, intelligence, surveillance, and reconnaissance.

> MR-1603-AF, *Interoperability of U.S. and NATO Allied Air Forces: Supporting Data and Case Studies*, Eric Larson, Gustav Lindstrom, Myron Hura, Ken Gardiner, Jim Keffer, Bill Little

NATO's Eastern Agenda:
Addressing the Challenges of a New Strategic Era

Since the end of the Cold War, NATO has sought to overcome the traditional division between Eastern and Western Europe. As a result, the Alliance's recent agenda has centered on eastward enlargement. This step has been undertaken not in response to any new military threat but to help export stability eastward and to prevent the emergence of a security vacuum in Central and Eastern Europe. NATO's enlargement is part of a broader strategic agenda designed to unify Europe and reshape the Alliance to deal with new threats—most of which come from beyond Europe's borders.

The Prague summit, held in November 2002, represented an important stage in NATO's evolution and approach to the East. At the summit, the NATO Heads of State and Government agreed to extend membership invitations to seven countries—Bulgaria, Estonia, Latvia, Lithuania, Romania, Slovakia, and Slovenia. In inviting these countries to join the Alliance, NATO took a major step toward overcoming the division of Europe and creating a "Europe whole and free."

However, NATO's Eastern agenda is by no means finished; it has simply been transformed. As discussed below, NATO still faces a range of important security challenges.

Encourage Democratic Consolidation and Military Reform in Central and Eastern Europe

The addition of Hungary, Poland, and the Czech Republic to NATO in 1997 helped to stabilize Central Europe and reduced the prospects that it will again become a major threat to European society. The second round of enlargement is expected to do the same for those countries that received invitations in Prague (see Figure 2). However, NATO first needs to ensure that the democratic transitions in the countries invited in the first round of enlargement are consolidated and that that these new members live up to their commitments to the Alliance.

The challenge facing NATO will grow with the need to integrate seven new member countries. It will be important for NATO to ensure that the addition

Figure 2—NATO's Eastern Enlargement

of the new members does not weaken the Alliance's military effectiveness or political cohesion. While many of the candidate countries have made progress toward modernizing their militaries in the last few years, their forces remain well below NATO standards.

Because these counties lack the financial resources to develop high-tech weapon systems, NATO should encourage them to develop niche capabilities and specialized units to fill gaps in the Alliance's overall military capability. To

strengthen military ties, the United States should consider using training facilities in Eastern Europe and redeploying some of its forces from Western Europe to this region. Any restructuring of the U.S. force posture, however, should be undertaken only after careful study of the broader political, economic, and military costs of such a move and only after consultation with European allies in NATO.

Ensure the Security of the Baltic States

The most difficult part of the enlargement puzzle concerns the Baltic region (Estonia, Latvia, Lithuania). Many Western officials and observers have long argued against Baltic membership out of concern that such a move would seriously damage NATO's relations with Russia. Now that the Baltic states have been invited to join the Alliance, they run the risk of becoming victims of their own success, as Western attention begins to shift elsewhere.

Thus, one of the key items on the new agenda is to maintain U.S. engagement in the Baltic region. In addition, the United States and its European allies need to ensure that the Baltic countries receive a militarily credible commitment for collective defense (Article 5). Western policymakers should further engage the Baltic states to ensure that there is no backsliding away from democratic reform and social tolerance.

Policymakers must also intensify efforts to engage Russia more deeply in regional cooperation schemes. Greater attention needs to be paid to stabilizing Kaliningrad, which became part of the Soviet Union following World War II and remains a Russian enclave today. If the economic gap between Kaliningrad and its neighbors continues to increase and Moscow does not deal effectively with the region's problems, it could lead to the growth of separatist pressures in Kaliningrad. Because Kaliningrad is a sensitive issue for Moscow, the United States may prefer to encourage others, especially the European Union and Nordic states, to take the lead on this issue.

Develop a Post-Prague Strategy for Ukraine

Ukraine's emergence as an independent state radically transforms the security equation in Europe. Strategically, an independent Ukraine acts as an important buffer between Russia and Central Europe and makes it more difficult for Russia to reemerge as an imperial power. Thus, it is strongly in the West's inter-

est to support and encourage Ukraine's closer association with and eventual integration into Euro-Atlantic institutions. However, a slowdown in reform in Ukraine in the last several years has raised questions about Ukraine's ability to achieve its "European choice."

Western policymakers need to look beyond current problems and develop a coherent, long-term strategy toward Ukraine. This need became all the more urgent following Ukraine's decision in May 2002 to formally apply for NATO membership. Ukraine has a long way to go before it qualifies for membership. Civilian control of the military is weak, and the market economy is underdeveloped. NATO needs to work with Ukraine to help improve its qualifications, particularly in carrying out comprehensive military reform. The Partnership for Peace (PfP) program can help Ukrainian military forces work more efficiently with NATO forces. The United States and its European allies should also continue to encourage economic and political reforms.

Incorporate Russia into a Broader European and Euro-Atlantic Security Framework

President Putin's decision to support the United States in the war on terrorism has opened new prospects for developing a more cooperative partnership between Russia and NATO. The newly created NATO-Russia Council, established in May 2002, provides a vehicle for doing this. The success of the new council, which supersedes the old Permanent Joint Council, will depend to a large extent on its ability to promote practical cooperation in areas of common interest. Rather than becoming stalled on procedural issues, NATO and Russia should identify a few specific area of cooperation where they can show tangible results quickly.

NATO must also begin to think about its longer-term goals vis-à-vis Russia, although it may be premature to identify a desired endpoint. Russia has not expressed an interest in NATO membership, and its transition is far from complete. However, if collaboration between Russian and Western states gradually deepens and expands, a different type of relationship could develop over time.

Develop a Strategy Toward the Balkans and the Caucasus

While the Balkans are today more stable than in the mid-1990s, the area remains highly volatile. NATO must determine what role it can and should

play in enhancing stability in the area. In the wake of the Afghanistan conflict, the Caucasus and Central Asia are likely to take on growing importance in Western and especially U.S. strategy. Thus, NATO will need to develop a more coherent strategy toward the region.

In most instances, PfP will serve as the best vehicle for developing cooperation with countries in these regions. The main focus of such cooperation should be on activities such as search and rescue, disaster relief, and peace support operations. Western policymakers also need to continue to nudge regional rulers toward greater openness and reform.

NATO's Eastern Agenda Can Help the Alliance Address New Security Threats

NATO has entered a new strategic era. Today, the Alliance must be prepared to deal with new threats such as terrorism and the proliferation of weapons of mass destruction. Managing these challenges, both in the East and beyond Europe's borders, will require enlightened and sustained U.S. leadership.

At the same time, although the United States is the world's sole remaining superpower, it cannot solve all problems on its own. Many of the challenges the United States faces—especially the war on terrorism—require cooperation with America's European allies and other partners. Thus, NATO will remain an essential forum for coordinating Euro-Atlantic strategic cooperation as well as a vehicle for developing the military capabilities to deal with both old and new challenges.

MR-1744-AF, *NATO's Eastern Agenda in a New Strategic Era*, F. Stephen Larrabee

Speeding Expeditionary Aerospace Force Deployment Through Footprint Reconfiguration

In recent decades, the U.S. Air Force has been frequently deployed overseas, often on short notice, in support of crises ranging from humanitarian relief to Operation Desert Storm. To meet these challenges, the Air Force introduced a new operational concept, the Expeditionary Aerospace Force (EAF), which replaces the permanent forward presence of airpower with a force that can deploy quickly from the continental United States to other locations. In implementing the EAF, the Air Force divided its forces into roughly 10 Aerospace Expeditionary Forces (AEFs), each with a mix of fighters, bombers, and tankers. An AEF is expected to begin operations immediately on arrival and sustain those operations as needed. However, quickly deploying the support for aerospace operations is challenging, largely due to the weight of the equipment and personnel required for a combat deployment. Because of the difficulties of speedy deployment, there has been a move toward reducing deployment "footprint" by cutting down the amount of materiel and people needed. This method of reduction is limited by current technology and the speed with which smaller, lighter equipment and munitions can be developed.

PAF researchers analyzed deployment data from 1996 through 2001 to define a baseline footprint and to develop a method for reducing deployment time by balancing tradeoffs among materiel, personnel, and support services. The traditional concept of footprint was simply the mass of materiel and number of people to be moved. The researchers proposed a new concept of footprint that treats its components as individual parts that can be prioritized and sequenced to reduce deployment time. Instead of focusing solely on physical footprint reduction, PAF recommended that the Air Force adopt a new approach known as footprint configuration, which will enable use of other strategies, such as time-phased or remote support, to reduce deployment times.

Traditional Footprint Reduction Has Proceeded Without a Specific Method

With the advent of the EAF concept, the Air Force can no longer assume that most deployments will be to fully equipped, "warm" bases. For deployments to

austere bases, all the materiel and personnel to begin and sustain operations—the entire deployment footprint—must be provided for, whether it is moved in or positioned ahead of time. Logistics planners must understand footprint on three levels: the individual support process, the complete package needed for a specific force/base combination, and the package needed for a theater composed of multiple forces located at multiple bases.

The researchers focused on five of the heaviest support processes—bare-base housekeeping, munitions, civil engineering, vehicles, and medical—to see how the footprints of these processes have changed since the inception of the EAF concept in 1997. They found that there has been little physical reduction in these areas. Munitions and earth-moving equipment have not changed over the years, and firefighting standards have come to demand more equipment and personnel than before. Independent efforts have been made within these support categories to reduce footprint, but they have focused on improvements in their own areas rather than on the goal of reducing deployment time over the entire base. The results have been suboptimal, with occasional conflicts between the actions taken by different areas. The researchers also found that within some areas strategies were developed to speed deployment—e.g., time-phasing support, providing support from centralized locations, and refraining from deploying any capabilities that were not specifically needed.

Footprint Configuration Offers a Framework for Integrating Footprint Reduction

To evaluate the many existing reduction strategies, PAF developed the concept of footprint configuration, in which the materiel and personnel required for any support process are divided into the following five parts:

- *Initial operating requirements (IOR)* include materiel and personnel needed at the forward operating location (FOL) to begin operations.
- *Full operating requirements (FOR)* include the materiel and personnel needed at the FOL to sustain operations and to bring the base to full operating capacity.
- *On-call requirements* are needed at the FOL but only in specific circumstances.
- *Forward support location (FSL) requirements* can be provided at locations elsewhere in the theater and need not be at the specific FOL.

- *Continental U.S. support location (CSL) requirements* can be accessed from the continental United States and need not be at the FOL or in the theater.

Different support processes are likely to have different components, as shown in Figure 3. The advantage of the footprint configuration framework over previous approaches to footprint reduction is that it recognizes the relationships among the different components that make up the footprint. It takes into account tradeoffs in deployment time, costs, and risks across strategies and functional areas to reduce deployment time for forces, not just individual areas.
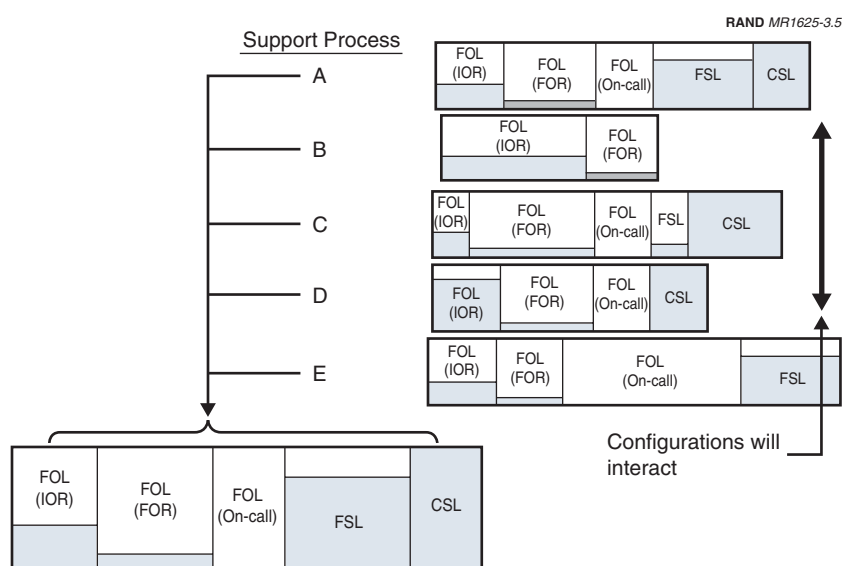
Figure 3—Combining Footprint Configurations for Multiple Support Processes

Specific Steps Will Help Reduce AEF Deployment Time

Focusing on simple physical footprint reduction creates problems because it encourages each support area to meet its own goals while ignoring capabilities that must be provided by others in the force. Because the primary goal is to speed deployment for a force to a base, footprint reconfiguration efforts should be concentrated at the force/base level. Although strategic decisionmakers are primarily interested in the resources required by a theater, the theater is composed of forces deploying to selected bases, so the force/base level is key to the assessment of the theater as well. Given these interrelated priorities,

PAF recommends that the Air Force implement footprint reconfiguration by taking the following steps.

- *Develop a comprehensive list of the units needed to deploy specific force capabilities to different base infrastructures.* Such a standardized list is critical to expeditionary planning because it will allow the Air Force to track the speed of deployment for a range of forces and destinations. And although it should not replace deliberate warplans, it could provide a starting point for and help speed the development of those plans.

- *Use the concept of footprint configuration to organize the restructuring of support processes.* Organizing all of the strategies in a common framework with a clear set of metrics will make it easier to select the appropriate strategies for individual support processes.

- *Give control of unit development to major commands and the Air Staff.* Although the involvement of process experts is essential, the reengineering effort needs centralized oversight to ensure that the proposed changes offer the largest possible payoff at the force/base level.

- *Track changes in deployment speed to evaluate progress.* The best way to evaluate progress in footprint reconfiguration will be to monitor the speed of deployment for selected force and base infrastructures.

- *Set up a system to evaluate force/base combinations at the theater level to assist warplanners.* Recent operations in Kosovo and Afghanistan suggest that many major operations need to draw forces and support from several combatant commanders. Thus, a tracking system to enable leadership to evaluate all warplans as a whole may become essential.

- *Develop tools to help decisionmakers evaluate and select among alternative footprint configurations.* Because it is unlikely that a single footprint configuration will be superior in every way, decisionmakers will need a rigorous method to weigh the possible configurations and reach a decision.

MR-1625-AF, *Reconfiguring Footprint to Speed Expeditionary Aerospace Forces Deployment*, Lionel A. Galway, Mahyar A. Amouzegar, Richard J. Hillestad, Don Snyder

Linking Resources to Readiness: How to Improve the Treatment of Logistics Resource Issues in the Air Force Planning, Programming, and Budgeting System Process

Since the end of the Cold War, the Air Force has struggled to adapt its logistics system to continuously changing weapons systems and repeated budget cuts. Reviews by the General Accounting Office and Air Force Materiel Command Reparable Spares Management Board have concluded that the Air Force's current logistics system is insufficient to support weapons systems effectively. There have been two kinds of problems. First, logistics budgets have not increased enough to keep up with needed improvements. Recent increases have not been sufficient to compensate for many years of underfunding. Second, the current logistics system reflects a number of internal problems including fragmentation, insufficient training, inadequate data systems, and inconsistent supply chain practices. The Air Force Director of Supply asked PAF to address the first of these problems by looking for ways to improve how the Air Force logistics community participates in the Air Force Planning, Programming, and Budgeting System (PPBS) process.

The Air Force's PPBS cycle is the procedure through which the Air Force identifies its resource needs. It is a complex process designed to take place over a three-year period. It begins with the development of specific defense plans from the Office of the Secretary of Defense (OSD). The OSD gives its plans to the Headquarters, Air Force (HAF), which in turn gives guidance to the major commands. The major commands then develop detailed programs and budgets to carry out the defense plans. The HAF resolves conflicts in the inputs from the major commands and gives the resulting plan to OSD. OSD works with the Air Force to refine the plan before submitting it to Congress, which uses the proposal as a starting point in developing its final budget.

PAF researchers analyzed the PPBS process through direct observation and structured interviews with selected key participants. They focused on the logistics of handling depot-level reparable (DLR) spares, which represent a large portion of the total logistics budget and offer many opportunities for improvement. However, many of the recommendations can be generalized to the rest of the supply chain. The researchers recommend strengthening the capabilities of the Air Force logistics community and involving logisticians more actively

in planning and budgeting. Complementary initiatives already underway may facilitate these changes, but the Air Force will have to address cultural factors that have prevented it from managing its logistics and supply chain activities more effectively.

The Current PPBS Process Suffers from Decentralization and Insufficiently Trained Personnel

Within the Air Force, the PPBS process is used to develop requirements, programs, and budgets for logistics activities. However, rather than ensuring adequate resources for supplies and support, the current Air Force approach to PPBS complicates problems that already exist in the supply chain. First, the process decentralizes decisionmaking on issues that would benefit from an integrated view. For example, it allows individual major commands to make decisions about their individual needs for items, but it fails to consider the economies of scale that would result from combining the requirements of all units Air Force-wide. A second problem with the process is that the individuals involved are not sufficiently trained to translate logistics requirements into needs that clearly relate to the Air Force's strategic goals. Officials responsible for managing logistics policy and resources have little training and experience in the PPBS process; therefore, they are ineffective in advocating for logistics needs in the planning and budgeting process. The existing Air Force analytic methods offer only limited help to Air Force planners who deal with these challenges.

Specific Actions Will Improve the Handling of Logistics Issues in the PPBS Process

The segmentation of the DLR supply chain and the lack of coordination in the PPBS process represent systemwide difficulties in the Air Force. Problems such as persistently low mission-capable rates highlight the need for changes in the way the Air Force programs and budgets for DLR spares. PAF recommends the following set of policy changes to the PPBS process to improve the Air Force's handling of DLR spares. These recommendations can be applied to other materiel items as well.

- Reframe logistics issues relevant to DLRs in the PPBS process to represent a realistic level of readiness achievable within designated resource constraints.

- Have logisticians participate more actively in the planning segment of the Air Force PPBS process to ensure that logistics is represented fairly in high-level PPBS considerations.

- Conduct the Air Force Planning and Programming Guidance (APPG) process so that it requires program proposals from the major commands to adhere to the stated fiscal constraints.

- Develop a process to monitor conflicts within the PPBS process itself and differences between logistics budgets and actual logistics needs each year.

- Strengthen the responsibility and authority of the Air Force Deputy Chief of Staff, Installations and Logistics, to act as the organization's senior logistician, integrate logistics requirements horizontally, and advocate for these requirements in the PPBS process.

- Provide training to increase the capability within the Air Force logistics community to participate effectively in the PPBS process.

- Build and sustain a credible analytic capability to support the above actions.

These changes, illustrated in Figure 4, comprise an integrated approach to improving the treatment of logistics in the PPBS process. A senior logistician could serve as a proponent and provide a single point within the Air Force for integrating input from the many parties whose needs affect planning, programming, and budgeting for Air Force-wide strategic goals.

Complementary Initiatives May Facilitate Effective Change

Three initiatives already underway in the Air Force should make it easier to implement the suggested policy changes: the Spares Campaign, the Air Force Resource Allocation Process, and the balanced scorecard. The Spares Campaign is an initiative to centralize funding of spares. The handling of DLR spares would benefit greatly from integrated management, and the Spares Campaign approach could reduce the problems caused by the current decentralized PPBS process. The Air Force Resource Allocation Process is a method to link specific Air Force capabilities to the resources required to enable them. If implemented properly, it would complement PAF's recommended changes and provide a link between strategic decisions and resource planning. The balanced scorecard is a proven commercial method to align an organization's behavior with its strategic goals and drive continuous improvement. The Air Force Logistics Transformation Team is currently developing a prototype balanced scorecard
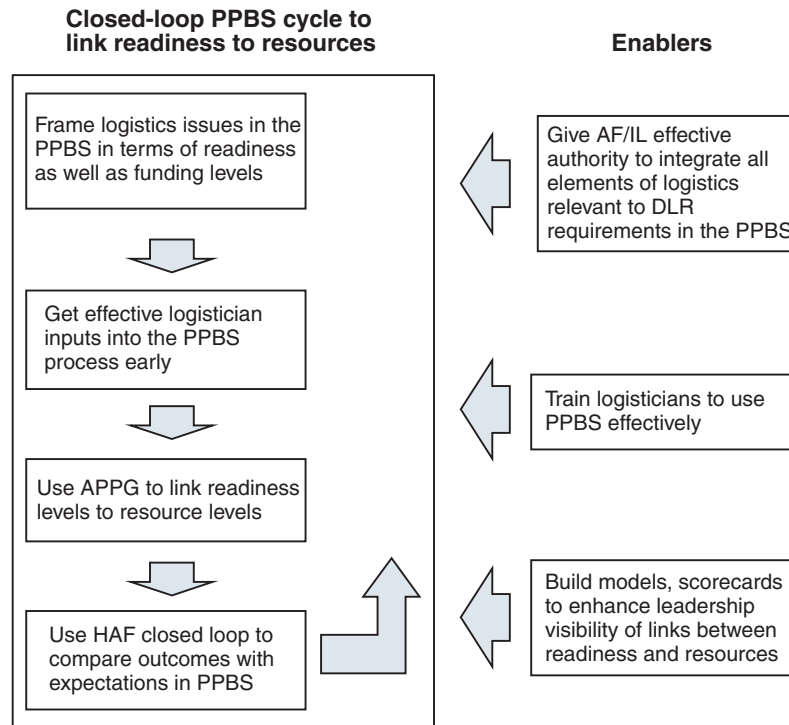
RAND*MR1611-3.1*

Closed-loop PPBS cycle to link readiness to resources   **Enablers**

Frame logistics issues in the PPBS in terms of readiness as well as funding levels

Give AF/IL effective authority to integrate all elements of logistics relevant to DLR requirements in the PPBS

Get effective logistician inputs into the PPBS process early

Train logisticians to use PPBS effectively

Use APPG to link readiness levels to resource levels

Build models, scorecards to enhance leadership visibility of links between readiness and resources

Use HAF closed loop to compare outcomes with expectations in PPBS

Figure 4—Integrated Package of Proposed Changes

for the operation and support of the F-16 fleet. If designed correctly, this score-card would clarify the relationships critical to the supply chain for DLRs and complement the recommended changes.

Improving the Treatment of Logistics Issues Means Challenging Organizational Barriers

To effect the recommended changes, the Air Force will have to confront funda-mental elements of its organizational culture. The way it handles logistics resources in its PPBS process today reflects deep-rooted traditions that color the organization's treatment of many issues. For example, the Air Force prefers to organize itself according to functions, such as supply and maintenance, rather than integrated processes, such as supply chains. Therefore, it lacks a sys-tem of authority and accountability for the combined processes that make up the supply chain. In addition, decisionmaking is not focused on systematic and

continual change, which is critical to improving logistics. Each policy or process change occurs in an isolated manner, not as part of a long-term integrated strategy. And when policy changes are made, the organization does not tend to follow up with efforts to ensure that changes proceed as planned. Finally, the Air Force tends to favor investments in modernization and new technology rather than those in process improvements.

The above recommendations for improving the treatment of logistics challenge the Air Force's traditional values but can succeed if implemented carefully over time. Individuals with responsibility for promoting these changes should be prepared to carry them out in an incremental fashion that demonstrates improvement over the long run. Each improvement can build the case for further change and encourage a method of resource allocation that treats logistics as an important component of organizational readiness.

MR-1611-AF, *Effective Treatment of Logistics Resource Issues in the Air Force Planning, Programming, and Budgeting System (PPBS) Process*, Frank Camm, Leslie Lewis

Aging Aircraft:
How Will They Affect Maintenance Workloads?

Since the end of the Cold War, lower defense budgets and higher costs for military aircraft have compelled the Air Force to keep its aircraft fleets in service for unprecedented lengths of time. To ensure safety and to preserve force size, the Air Force will need to invest more funds and personnel in maintenance. Until now, there has been no mechanism to predict how much additional maintenance aging aircraft will require.

As part of an ongoing study of the effects of aging aircraft on Air Force budgets and force planning, PAF developed a mathematical model to calculate how maintenance requirements increase over an aircraft's life. Preliminary findings include the following:

- As expected, maintenance requirements rise as aircraft grow older. Aircraft undergo various types of maintenance, which may be performed on the flightline, at the base, or in the depot. The number of man-hours necessary to perform each category of maintenance increases over the life of the aircraft. The only exception is periodic inspection, which is performed at regular intervals and does not change. This finding suggests that maintenance requirements will continue to rise as long as older fleets are kept in service.

- Complex aircraft require more late-life maintenance than simpler aircraft. Larger aircraft have more complex machinery and thus take longer to inspect and service. A cargo plane will not only require more maintenance than a fighter aircraft at any given age, but the amount of service it needs will rise at a faster rate over time.

This research suggests that the Air Force should prepare itself for significant changes in maintenance requirements. In recent years, corrosion and wiring deterioration have unexpectedly increased the demand for inspections and maintenance of older aircraft. Further concerns may yet emerge. The Air Force should hedge against potential upturns in maintenance workloads. A possible strategy is to set a "trigger point" for maintenance workloads at which the Air Force would begin to purchase new aircraft rather than bear the expense of additional maintenance.

PAF is currently using this model to predict the cost and manpower implications of rising maintenance needs among specific fleets. Air Force decision-

makers will be able to use these data to adjust future budgets, acquire additional manpower and maintenance capacity, and set trigger points for replacing older fleets.

MR-1641-AF, *Aging Aircraft: USAF Workload and Material Consumption Life Cycle Patterns*, Raymond A. Pyles

Assessing the Effects of Advanced Materials on Airframe Operating and Support Costs

Because of their superior strength and lighter weight, advanced materials such as polymer composites and titanium have in recent years been increasingly used in the airframes of high-performance military aircraft. In the 1960s and 1970s, composites constituted only a very small percentage of the structural weight of military airframes. Today more than 20 percent of the airframe structural weight of modern fighter aircraft comes from composites. Because these materials differ greatly from the aluminum prevalent in earlier aircraft, understanding how their use affects the operating and support costs of fielded military airframes is very important in decisions on airframe acquisitions and choice of materials. To address this question, PAF researchers analyzed data from the B-2 Program Office, airframe contractors, and F/A-18 maintenance records to identify differences in operating and support costs. They looked specifically at frequency of repair, cost of consumables, and the labor hours required for maintenance and found that the use of advanced materials does affect operating and support costs. Titanium requires less maintenance than aluminum. Composites, especially those with aluminum honeycomb substructures, require more. Deciding which material to use on each part type is critical in determining the maintenance costs of advanced materials as compared with aluminum.

A Substantial Portion of a Fighter Aircraft's Exterior Is Made of Advanced Materials

The external surface of the airframe is the area that requires the most maintenance; and, in modern fighter aircraft, it is composed largely of advanced materials, as shown in Figure 5. This area of an airframe has the greatest probability of damage due to a number of factors including human error, foreign object damage, environmental corrosion, and aerodynamic stress-induced fatigue. The airframe components that require the most maintenance are the edges, skins, doors, and panels, which are more commonly made of advanced materials in fighter aircraft. Access doors, covers, and skins make up about 15 percent of the airframe weight in a typical modern fighter aircraft.
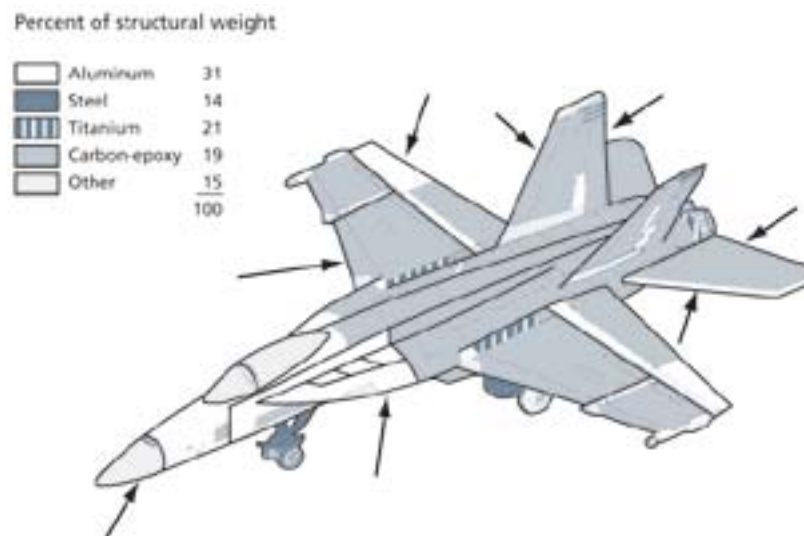
Percent of structural weight

☐	Aluminum	31
■	Steel	14
▥	Titanium	21
▥	Carbon-epoxy	19
☐	Other	15
		100

Figure 5—Airframe Edges, Skins, Doors, and Panels Are the Parts Most Susceptible to Damage

Maintenance Requirements Differ Depending on Part Type and Composition

Using F/A-18 maintenance data, the researchers found that maintaining skins and access covers required almost the same amount of labor, while access doors required the most labor of the three. Access doors also required more consumables than the other two types of parts. Analyzing different types of materials within part types, the researchers found that parts made of titanium required the least maintenance for both skins and access covers. Aluminum skins and access covers required more maintenance than titanium ones, and those made of graphite epoxy sheets with aluminum honeycomb substructures required the most maintenance.

The Current Use of Titanium and Composites Lowers Costs

When the researchers compared the labor and consumables costs for different hypothetical airframe structures to the baseline of an all-aluminum airframe, they found that an all-titanium airframe would be the most attractive option for reducing the costs for both labor and consumables. Use of an all-titanium

airframe would result in savings of approximately 45 percent in labor costs and more than 35 percent in the cost of consumables. On the other hand, an airframe using only graphite epoxy, a composite material, would increase the labor costs by about 45 percent and the consumables costs by more than 25 percent. The airframe structure most common in modern fighter aircraft incorporates a combination of graphite epoxy and titanium, with all-titanium access doors the most maintenance-intensive part. Compared to an all-aluminum airframe, this construction saves approximately 40 percent in labor costs and nearly 30 percent in the costs of consumables. While this is slightly less than the savings offered by a hypothetical all-titanium airframe, the cost-effectiveness is substantial compared to the use of aluminum.

DB-398-AF, *The Effects of Advanced Materials on Airframe Operating and Support Costs*, Raj Raman, John C. Graser, Obaid Younossi

A Simulation Model for Evaluating Jet Engine Intermediate Maintenance Alternatives

The Jet Engine Intermediate Maintenance (JEIM) shop has traditionally been located with the fighter unit it supports. However, expeditionary requirements for quick deployment, along with other considerations such as the increased complexity of engines and the large investment required for repair facilities, have led the Air Force to consider whether intermediate maintenance ought to be centralized off-base. To evaluate alternatives for accomplishing JEIM support, PAF researchers developed the Engine Maintenance Systems Evaluation (EnMasse), a suite of simulation models based on Extend software.

EnMasse has several features that make it particularly useful for analyzing maintenance systems.

- *EnMasse offers dynamic modeling capabilities that allow the user to create a realistic simulation of the jet engine repair system.* EnMasse's structure is based on a set of hierarchical, functional blocks representing such entities as Air Force home bases, flightlines, JEIM shops, module shops, test cells, forward support locations (FSLs), and forward operating locations (FOLs). The model simulates the interaction among the components of the maintenance system, allowing users to evaluate a number of possible support configurations for the JEIM and to compare alternatives for maintenance support across different scenarios.

- *The EnMasse simulation can directly incorporate the variation and uncertainty typical of a maintenance system.* EnMasse allows users to track many dynamic metrics of interest, such as the number of sorties missed and queue sizes at key maintenance shop points. The model also gives users flexibility in setting time dimensions, engine "demographics" (e.g., age distribution in terms of cumulative flying hours), and repair modes (e.g., whether scheduled for inspection or maintenance). With EnMasse, users can analyze potential transportation options at a relatively high level of detail and can incorporate a number of transportation variables, such as transportation capacity and schedules.

- *With EnMasse, users can identify individual engines and aircraft and capture detailed information about their status and progress in events ranging from flying sorties to maintenance.* Crucial management decisions in engine repair are based on these characteristics, and EnMasse allows decisionmak-

ers to evaluate potential alternative maintenance polices, such as reliability-centered maintenance.

*   *EnMasse is flexible enough to be used for further analysis in future expanded studies of engine repair.* Future studies might incorporate a number of other important characteristics, such as the management of engine deployment and repair based on the time characteristics of individual engines, the effects of engine demographics and different management decisions on JEIM and depot workload, more detailed representations of repair modes based on whether an engine removal is scheduled or unscheduled, and transportation policies.

Extend software (and ultimately EnMasse) is somewhat limited in terms of input and output generation. Further work may be needed to make the model easier to use. A centralized external database where all possible input parameters could be read would greatly enhance EnMasse and allow for a better parametric analysis of the system. Although the current version of Extend allows for basic sensitivity analysis, this feature is not flexible enough and will require additional coding for certain analyses.

MR-1614-AF, *Supporting Expeditionary Aerospace Forces:
Engine Maintenance Systems Evaluation (EnMasse)—A User's Guide*,
Mahyar A. Amouzegar, Lionel A. Galway

The Military Uses of Space: Next Steps for the Air Force

In 1999, the U.S. Congress established a Space Commission to assess the nation's arrangements for developing the military uses of space. This action was motivated by concerns that the Air Force was not adequately carrying out its long-held stewardship over the U.S. military space program. In particular, the Commission was asked to explore whether the United States should create a separate and independent Space Force, similar to the creation of the Air Force in 1947. In its final report, released in January 2001, the Commission concluded that the creation of a separate space service was not warranted—at least not yet. However, it determined that the nation was not developing the military space cadre it needed; that military space projects were underfunded given their growing importance to U.S. national security; and that, without adequate protection of U.S. satellites against a space-capable aggressor, the nation faced the possibility of a future "Pearl Harbor" in space.

To address these issues, the Space Commission recommended that the Air Force be formally designated the executive agent for space within the Department of Defense (DoD) and that it be given oversight authority over all DoD space programs. The Commission also recommended that the DoD create a separate budget category for space programs to ensure greater transparency in space-related spending by all military services. The Secretary of Defense accepted these recommendations and has taken actions to implement them. Thanks to these developments, the Air Force entered the twenty-first century with a formal mandate and a set of important challenges in need of attention.

This study addressed the most pressing military space issues that the Air Force now faces. It reviewed the main milestones in the Air Force's involvement in space, explored the organizational and conceptual roadblocks that have impeded a more rapid growth of U.S. military space capability, and considered the circumstances that led to the creation of the Space Commission. Finally, it recommended steps that the Air Force should take to realize its mandate as executive agent for space.

Custody of Space Was Never an Air Force Birthright

Most airmen assume that space has been a natural operating domain of the Air Force ever since the start of U.S. military involvement in this arena. On the contrary, since the end of World War II, the Air Force has constantly vied with other military services and with the political establishment for control of the nation's military space effort. Even a cursory review of this history shows that the Air Force became the *de facto* custodian of the nation's military space program more by organizational persistence than by any natural selection process. The Air Force leadership had to fight at every step of the way to earn its dominant role. The history of this struggle is well worth remembering by today's Air Force planners because it offers a cautionary note against presuming that space has somehow been a due and rightful inheritance of the Air Force.

The "Aerospace" Concept Has Impeded the Air Force's Progress in Space

For five decades, the Air Force has been fundamentally divided over the issue of whether air and space should be treated as two separate operating mediums or whether these environments constitute a single and seamless continuum known as "aerospace." The "aerospace" concept was first enunciated by General Thomas D. White in 1958. Early proponents used the idea to justify an expanded operating arena for future Air Force assets against the rival claims of other services. However, the notion of air and space as a single medium was flawed from the start. The Air Force advanced the "aerospace" idea almost entirely by fiat, with little serious analysis or systematic thinking to underpin it. Moreover, the concept was pressed into Air Force doctrine without regard for the important physical and operational differences that exist between air and space. Advocates did not even try to offer a convincing basis for explaining and justifying what the Air Force's role in space should be or how its space missions should be fulfilled.

The Air Force's long portrayal of "aerospace" as a single operating medium has had two important undesirable consequences.

- *The Air Force has not developed a systematic approach to the military use of space.* Although proponents of the two-medium concept rightly succeeded in locating Air Force space activities within a distinct command in the 1970s, the "aerospace" formulation has remained the primary frame of reference for the service's thinking about space. As a result, the Air Force has

routinely treated air and space as separate mediums in its day-to-day operations, while its doctrines and policies have—until very recently— clung to the "aerospace" concept. An unfortunate consequence is that, although the Air Force has succeeded in developing a preeminent military space capability for the United States, it has made far less progress in developing an agreed basis for thinking systematically about what the U.S. military should be doing in space.

- *The Air Force has had to make unnecessarily difficult tradeoffs between air and space systems in its resource allocations.* As long as the Air Force had so little of its annual budget committed to the space portion of "aerospace," it could easily accept a vision that proclaimed both arenas as its rightful domain. Once the Air Force began to invest in space in a serious way, however, it quickly learned that its embrace of "aerospace" had confronted it with the need to fund what were, in fact, two costly mission areas with a budget share allotted for only one.

The Space Commission heard the Air Force's argument on behalf of "aerospace" as a single operating medium but did not agree with its premises and assumptions. Instead, the Commission concluded that space is a separate operating arena equivalent to the air, land, and maritime environments and that it is overdue for being treated as such. Not long thereafter, the Air Force leadership disavowed the "aerospace" construct and began to portray space as separate and unique, warranting its own organizational structure and career track. That change in mindset was very much in the Air Force's interest and should be made a permanent fixture of the service's thinking and rhetoric.

Space Control Is the Next Step

The United States has not yet had to face an adversary in space. However, the prospective emergence of new threats to U.S. space systems argues for the nation to take timely, preemptive countermeasures. Threats include the possibility of ground-based laser attacks against U.S. satellites, jamming of vital assets such as the Global Positioning System, and—in the worst case—a large-scale electromagnetic-pulse attack against U.S. satellites by means of a nuclear detonation in space. Given the growing potential for such attacks and the United States' mounting dependence on space-based capabilities, it is increasingly important that the Air Force develop and field effective space control measures aimed at ensuring the freedom of U.S. operations in space and denying such freedom to adversaries as circumstances may warrant.

As the Air Force proceeds to develop space control capabilities, it will need to navigate the popular and political sensitivities that have prevented many space weapons initiatives from coming to fruition in the past. In its public pronouncements, it should clearly differentiate between technologies involved in passive and active space control and those associated with space weapons aimed at attacking targets on the ground. Furthermore, while pursuing space control with its fullest determination, the Air Force should defer major involvement in offensive space weaponization against ground targets until there is a clearer justification and stronger political support for such investments.

Finally, the Air Force should ensure that adequate space control measures are in place before it migrates follow-on surveillance systems such as the Joint Surveillance Target Attack Radar System (JSTARS) and the Airborne Warning and Control System (AWACS) into space. Otherwise, the United States may risk turning its current technological advantage into a new vulnerability—all the more so if these assets supplant rather than merely supplement existing air-breathing capabilities. The Air Force should pay serious attention to any potential system vulnerabilities as it plans to migrate such assets into space. The potential risks to those assets clearly underscore the need to make the development of a credible space control capability the next U.S. military space priority.

Some Important Next Steps Can Improve the Air Force's Posture in Space

The assignment of executive-agent status to the Air Force for military space activities was a generation late in coming. Now that the Air Force has been granted that authority, it needs to take the following steps:

- Continue the operational integration of space with the three terrestrial warfighting mediums while ensuring the organizational differentiation of Air Force space programs from air programs.

- Realize a DoD-wide budget category for space that imparts transparency regarding how much money and manpower are going into space each year and for what purposes.

- Proceed aggressively toward developing a credible space control capability while decoupling that effort from any perceived taint of offensive weaponization against terrestrial targets.

- Work harder to nurture a cadre of skilled space professionals who are ready and able to meet the nation's military space needs in the coming decade and beyond.

Mastery of these challenges should not only ensure a satisfactory near-term future for the Air Force and the nation in space. It should also help the Air Force revitalize its eroded assets for meeting its no less important force-projection responsibilities in the air arena.

MR-1649-AF, *Mastering the Ultimate High Ground: Next Steps in the Military Uses of Space*, Benjamin S. Lambeth

Promoting Innovation and Modernization Within the United States Air Force

In today's highly dynamic security environment, the threats faced by the United States are changing rapidly, as are the types and nature of operations conducted by its military forces. Thus, it is crucial that the services promote innovation and modernization of their operational capabilities. Instituting a straightforward, coherent, and well-defined process for modernizing can help decisionmakers ensure that relevant capabilities are developed and fielded in a timely manner.

The current system for modernization within the Department of Defense centers on developing "requirements" for proposed systems. The prior and more important activity of actually defining new concepts is often overlooked. In addition, the current system dictates that innovators must seek permission from acquisition authorities before they can explore new concepts. This requirement inhibits the kind of creative thinking that should occur during the problem-solving process.

General John Jumper, who in 2001 became Chief of Staff of the Air Force, has sought to invigorate the process of modernizing the operational capabilities the Air Force provides. His approach uses "task forces" or teams, and it focuses broadly on concepts of operation to meet operational challenges rather than improving or "recapitalizing" specific forces, hardware, or programs. He has designated officers to serve as "champions" to promote new concepts for key types of operational capabilities and to monitor the status of the concepts within the Air Force's programming and budgeting process.

PAF developed a broad conceptual framework for promoting innovation and modernization within the Air Force that aims to help the Air Staff implement General Jumper's approach. The framework offers a clearly defined set of terms relevant to the consideration of military capabilities and concepts of operation. It identifies (generically) the principal actors within the Air Force who are responsible for guiding and promoting innovation. It also lays out a process governing the interactions among these principal actors, encompassing activities that range from strategic planning to providing the operational capabilities needed by warfighting units. Finally, it offers the leadership of the Air Force a list of operational capabilities derived from defense strategy and from joint-service employment concepts that could be used to organize the efforts of the "champions" designated by General Jumper.

The Terms in the Framework Have Been Carefully Chosen

The framework defines the primary elements of the lexicon relevant to military operations in a theater war. For example, PAF chose the words "modernizing operational capabilities" with some care. We could have used "modernizing forces," but that would suggest that the "forces" (types of units) remain the same and that existing types of platforms or units are being modernized. There is another reason to talk in terms of capabilities. The Air Force provides capabilities to combatant commanders and achieves these capabilities according to a concept of employment defined by the Air Force. If a service thinks of itself as simply "providing forces" to combatant commanders, it diminishes its role in the development of operational art within its medium.

Seven Principal Actors Are Responsible for Guiding and Promoting Innovation

Functionally speaking, seven principal actors are involved in the modernization process within a service.

- The Definer, whose primary role is to frame a finite set of high-priority operational challenges or requirements that the Air Force will strive to meet. Meeting these challenges involves developing new concepts for fielding new or significantly improved capabilities.

- The Conceivers, who formulate, define, and, when appropriate, demonstrate new "concepts of execution"—i.e., an end-to-end concept for accomplishing a particular operational task.

- The Proponents, who define new concepts of employment—i.e., concepts for achieving particular operating objectives. Each Proponent is responsible for monitoring and assessing the Air Force's capabilities to achieve a related set of operational objectives. The Proponents also seek to ensure that adequate resources are allocated within the Air Force to sustain and advance "their" set of operational capabilities. They also serve as advocates for resources to authorities outside of the Air Force (for example, in the Office of the Secretary of Defense and in Congress).

- The Independent Evaluators, who advise the Secretary of the Air Force and the Chief of Staff on the merit of any proposed new concepts.

- The Programmers, who estimate the cost of proposed concepts and suggest ways for balancing resources across all of the activities that the Air Force carries out.

- The Providers, who provide capabilities (not forces) to combatant commanders by implementing new concepts of execution and new concepts of employment. The acquisition of new platforms, weapons, and support systems falls under this rubric.

- The Secretary of the Air Force and the Chief of Staff, who preside over the entire process outlined above and render decisions at key points. Their responsibilities include the issuance of an approved list of operational challenges, the choice of whether to pursue a concept proposed by the Proponents, and how best to advocate that concept to gain the resources needed for implementation.

PAF suggests that a system for spurring and managing innovation can be fully established by defining the responsibilities of each of the actors and the relationships among them. We propose that Air Force leadership adopt the model shown in Figure 6 as its process for governing efforts to modernize the operational capabilities it provides to combatant commanders. In the figure a circle or an ellipse depicts one of the principal actors involved. Labels or arrows that go from one actor to another show the inputs and outputs attendant to each of the actors. Within each circle or ellipse, there is a terse statement as to the actor's functions or processes—that is, how the actor provides each output.

The process starts in the upper left hand corner with the strategic planners. These planners reside in the Office of the Secretary of Defense, the Joint Staff, the National Security Council, and in various think tanks. They issue a series of statements regarding the future operating environment, the possible missions of the U.S. armed forces, and the types of capabilities that they believe will be relevant to future military operations. Because the planners' statements are very general, the proposed framework calls for a Definer within the Air Force to specify key operational challenges that the Air Force should strive to meet—for example, being better able to locate and identify suspected terrorist groups or individuals in complex terrain.

The challenges specified by the Definers are translated into specific tasks for which Conceivers develop new concepts and technologies. Conceivers work independently to study operational challenges and propose solutions for them.

In practice, the Definer's statement of challenges sets the overall direction for everything that follows, with a very long timeline. If a Conceiver develops a new concept for fulfilling a particular challenge and a new major system or platform is required to implement the concept, seven to 10 years or more may pass before the new capability is a reality, and the concept may endure for
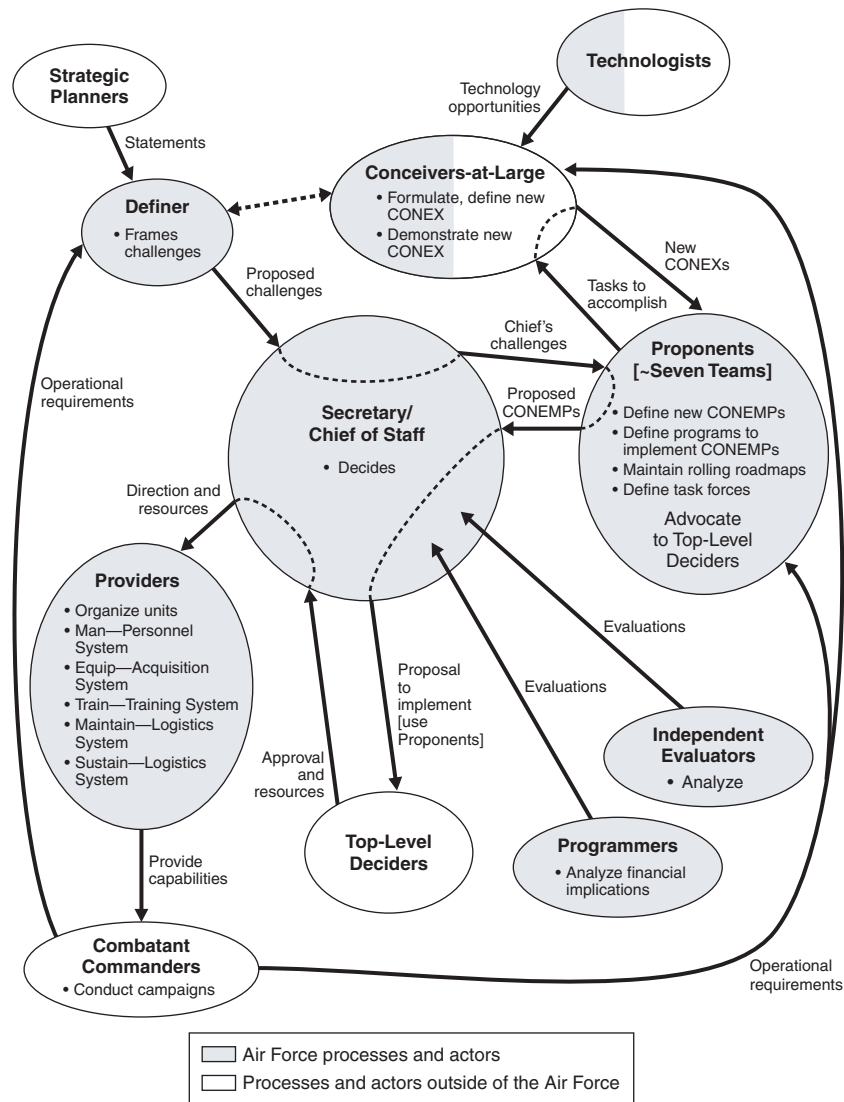
Figure 6—The Master Framework for Modernization

another 20 years or more. Thus, the work of the Definer may cast a shadow 30 or more years hence. For these reasons, the set of challenges developed by the Definer is sent to the Secretary and the Chief of Staff of the Air Force for their review, adjustment, and, finally, approval.

In the next step in the proposed framework, Proponents monitor the Air Force's ability to perform the tasks, and they advocate for resources when

improvements are necessary. The Proponents, who would be senior officers on the Air Staff, could cover the operational capabilities of greatest saliency to the Air Force. Their areas of responsibility could be allocated to seven "teams" and defined as follows:

- Team 1: Gain freedom to operate. This goal includes efforts to establish access in theaters of operations, to gain air superiority and space superiority over the enemy, and to sustain high-tempo operations at bases in the theater despite countervailing actions by the enemy.

- Team 2: Provide control of the operation of forces.

- Team 3: Provide strategic air mobility.

- Team 4: Fight and gain the effects desired in conflicts.

- Team 5: Protect the homeland.

- Team 6: Conduct global strikes.

- Team 7: Conduct other operations. This objective includes maintaining global awareness, providing a stabilizing presence in key regions, and providing humanitarian relief.

The Secretary of the Air Force and the Chief of Staff then decide which ideas merit implementation based on input from Proponents and Independent Evaluators.

The New Framework Offers Important Benefits

The utility of a simple and coherent framework (even though it may not be officially adopted) is evident when there is no obvious model to follow, or, if one exists, it lacks logic and coherence. The PAF framework adheres to the goal of promoting timely innovation in modernizing operational capabilities. It seeks to reemphasize the distinctions between concept development, which plays the central role in determining what systems to pursue, and acquisition, which is properly focused on how to develop and procure such systems. The goal is to minimize the constraints and strictures placed upon those charged with generating innovation and to level the playing field on which new concepts can compete for resources. The proposed framework offers several benefits.

- It is actor-oriented, as distinct from document-oriented. It defines the roles of the various actors in fostering and promoting modernization.

- The model's actors address matters that are focused at the operational and tactical levels, as distinct from a focus at the campaign level (a level higher).

- The model separates the processes of concept development and acquisition, ignoring any supposed requirement to ask "May I?" from some higher authority before engaging in the art and science of exploring new concepts.

- The model promotes enduring activities associated with the exploration and development of new concepts at three levels: new concepts of systems and platforms, new concepts for accomplishing military tasks, and new concepts for achieving operational objectives.

- By deriving operational challenges, objectives, and tasks from an examination of potential joint-service campaigns, the model promotes a joint perspective.

- The model is straightforward and adheres to a rigorous lexicon. This is not a trivial virtue, considering the proliferation of undisciplined vernacular and confusing slogans at large within the U.S. defense community today.

MR-1706-AF, *A Framework for Modernization Within the United States Air Force*, Glenn A. Kent, David A. Ochmanek

How Can the DoD Meet Its Demand for Satellite Communications Capacity?

Satellite communications play a key role in the DoD's plan to achieve information dominance in the battlefield of the future. Although DoD demand at the time of the 2002 study was under 4 gigabits per second (Gbps) of bandwidth, planners estimate that to effectively support joint-service operations the requirement will reach approximately 16 Gbps by 2010. However, under then-current procurement plans, the DoD will at that time own less than 15 percent of its projected desired capacity.

Important as satellite communications are, outright procurement of all capacity is cost prohibitive. Therefore, the DoD must be selective and prioritize essential services that require military-unique capabilities (for example, resistance to jamming or electromagnetic pulse). To meet the remaining demand, commercially leased satellites can be used to perform communications functions that require lower levels of protection.

PAF conducts ongoing research to help DoD develop efficient and cost-effective approaches to acquiring necessary satellite communications capability. The key outcomes of two recent studies are briefly summarized below.

- Military planners must determine in advance how much communications capacity to purchase and how much to lease in various parts of the world. To do this, they would benefit from an understanding of what drives growth in worldwide satellite capacity as well as from an ability to predict that capacity. PAF found that there is a strong relationship between growth in total satellite communications capacity and economic growth as measured by gross domestic product (GDP). Adjustment to change is rapid. If there is an imbalance in the long-run equilibrium between supply and demand, we estimate that, on average, 25 percent of the adjustment is made within one year, although there is some regional variation. Our analysis indicates that the market can adjust swiftly to a surge in demand, and thus there may be little need to buy satellite capacity in advance simply to ensure that it will be there if needed.

- To help planners determine the appropriate amount of communications capacity to lease under conditions of uncertain demand, PAF developed a simple, graphical technique that is based on an uncomplicated mathematical model. In addition, extensions to the model show how price uncer-

tainty and the ability to salvage unused capacity change the appropriate amount of capacity to lease. Finally, a multiple-period version of the model illustrates how communications planners can consider the tradeoffs between long- and short-term leases when demand grows over time.

MR-1613-AF, *The Dynamics of Growth in Worldwide Satellite Communications Capacity*, Michael G. Mattock

MR-1402-AF, *Optimal Commercial Satellite Leasing Strategies*, Michael G. Mattock

Estimating the Intelligence, Surveillance, and Reconnaissance (ISR) Requirements of Small-Scale Military Operations

When planning the mixture of ISR forces that the United States will need in the future, the Air Force should consider the unique requirements of small-scale operations in addition to those of major conflicts. In recent years, the United States has engaged in many small-scale operations, which include peacekeeping missions, humanitarian assistance, and counternarcotics operations. The Air Force supports these missions by detecting, monitoring, and tracking targets of interest and relaying information to U.S. or local authorities. These operations pose unique ISR challenges because they often involve limited access to local bases, rough weather and terrain, and small, fast-moving targets.

PAF studied several small-scale contingency scenarios to determine what ISR capabilities the Air Force would require. Researchers concluded the following:

- *Predator unmanned aerial vehicles (UAVs) are useful when visual identification is important and local basing is available. For example, to halt drug shipments across the U.S.-Mexican border, the Air Force must be able to identify suspicious trucks and track them among thousands of identical vehicles.* Predators equipped with optical sensors could deploy from bases in the area and could fly low enough to provide high-resolution images of trucks to border authorities.

- *Larger UAVs are better suited for remote ocean surveillance than smaller UAVs.* For example, preventing piracy against U.S. vessels at sea requires ISR aircraft to fly long distances and to hover over large spaces for extended periods of time. Large UAVs have longer endurance than Predators or manned aircraft. Once they arrive at a location, they could use optical or infrared sensors to look for ships departing from their courses or unusual rendezvous between vessels.

- *Foliage penetration radar is needed for operations in jungle environments.* Operations against narcotics producers require the Air Force to monitor suspicious facilities and shipments hidden beneath foliage and cloud cover. UAVs equipped with radar sensors could locate and track targets hidden beneath the jungle canopy.

PAF is conducting further research to help the Air Force determine the most cost-effective combination of ISR systems to support a broad spectrum of future operations that range from small-scale contingencies to major theater war.

DB-392-AF, *Intelligence, Surveillance, and Reconnaissance System Considerations Regarding Narcotics and Ocean Monitoring*, Sherrill Lingel, Michael Scheiern (Restricted distribution, not for public release)

A New Tool for Compensation, Accessions, and Personnel Management in the U.S. Military

Pay and other forms of compensation for military service are important factors in a person's decision to join the military or to reenlist. Since the introduction of the All Volunteer Force in 1973, it has been essential for policymakers to understand how changes in pay, retirement compensation, selective reenlistment, and other policies affect the military's ability to recruit and retain qualified personnel. These factors have become more critical as U.S. military operations expand overseas and U.S. personnel are subjected to greater operational strains. Indeed, some analysts predict that recruitment and retention rates will decline in response to the longer deployments and heightened risks experienced in Operations Enduring Freedom and Iraqi Freedom.

Policies regarding compensation, accessions, and personnel management in the U.S. military are developed by three separate directorates within the Department of Defense. Although these groups have organizational links, their analyses and decisions are often separated by technical and disciplinary barriers. Authorities lack common data and analytic tools to set mutual goals and to ensure that decisions made in one area do not conflict with other areas. To remedy this problem, PAF developed an integrated analytical tool that allows decisionmakers in all three areas to analyze and evaluate proposed changes in personnel policy with respect to the enlisted force. This tool is the Compensation, Accessions, and Personnel Management (CAPM) system.

CAPM Uses Econometric Models to Simulate Personnel Retention

The CAPM system is based on a simple assumption about employee retention: A rational individual faced with the decision either to stay in a position or to leave will compare the long-term benefits of each option and will choose the more valuable alternative. Value is primarily measured in financial terms, but it may include other factors such as an individual's taste for military service, the civilian unemployment rate, and the effect of personal attributes such as sex, race, and mental aptitude.

The annualized cost of leaving (ACOL) model replicates this decisionmaking process in mathematical terms. The model draws on databases of actual enlisted

personnel and uses equations to represent the full range of factors that can affect a person's decision to stay in the military or to leave. For example, an individual's taste for military service can be inferred from statistical analysis of historical data; this factor is essentially translated into a dollar equivalent that is added to other military compensation and weighed against the financial value of leaving. The model is also designed to replicate the realities of the employment market. For example, an individual's civilian pay partly depends on how long the person has been in the military, thus accounting for the benefits of military experience as well as the possible drawbacks of starting a new job late in one's career.

This model allows CAPM to predict how individuals in certain demographic categories—especially grade, sex, race, mental category, and years of military service—will respond to changes in military compensation policy. If the long-term benefits of military service fall below what a person believes he or she can make in the civilian sector, then that person is less likely to reenlist.

CAPM Provides a Standardized System for Analyzing Recruitment and Retention

The CAPM system operates on a personal computer spreadsheet. Policymakers and analysts can access the program through an easy-to-use graphic interface. In this way, CAPM provides authorities in different disciplines with a common set of terms, data, and methods for analyzing personnel-related policies. The main features of the system are as follows:

Decisionmakers create scenarios to represent policy options. The model begins with a baseline scenario that reflects current policies and the present composition of the enlisted force for a given military service. The user can alter the recruitment criteria, create incentives for voluntary termination, change the pay tables, adjust the cost of living for retired pay, or make a range of other policy choices. These actions may be designed to increase recruitment or to retain more personnel with certain skills. The user may also set goals for the total size of the force over a given period of time and see what personnel policies would be required to meet these goals. Finally, the user may change the baseline data to reflect assumptions about the composition of the initial force. This feature allows decisionmakers to assume future conditions or to limit the analysis to certain parts of the force. CAPM keeps a complete record of the assumptions, policies, and data used for each scenario. Thus decisionmakers can easily change the information to create multiple scenarios.

CAPM calculates reenlistment rates and projects future force size. Using the ACOL model, CAPM computes how changes in policy are likely to affect reenlistment rates in each demographic category—grade, sex, race, mental category, and years of service. Once the retention rates have been calculated, CAPM projects the number of personnel in each category over a given time period. The program takes into account the desired end strength of the enlisted force and allows for the possibility of "structural" controls such as limitations on the number of personnel in certain grades.

Decisionmakers can compare the outcomes of various scenarios. CAPM provides analytical tools such as tables and graphs that enable decisionmakers to see the implications of specific policy decisions. These results may be pasted into other documents and presentations for easy dissemination.

Two Examples Illustrate CAPM's Capabilities

Researchers examined sample scenarios to demonstrate CAPM's usefulness for personnel policy analysis. These sample runs yielded several important observations:

- *Relaxing educational standards for new recruits may increase recruitment requirements in the long run.* U.S. military services have expressed concern about meeting recruitment goals. One possible response to this problem would be to relax educational standards for new recruits. Researchers used CAPM to explore the potential ramifications of such a policy. Using Air Force personnel data from fiscal year 2000, researchers assumed that 50 percent of the recruits were high-aptitude white males (as measured by their performance on the Armed Forces Qualification Test) and that 15 percent were low-aptitude white males. The team then created an alternative scenario in which the recruitment goal for high-aptitude white males was reduced to 40 percent and the goal for low-aptitude white males was raised to 25 percent. The desired end-strength of the force was assumed to be the same for both scenarios. The CAPM system showed the likely result of this policy. Contrary to expectations, the total number of new recruits required to meet the end-strength goal increased by the fourth year of the projection. The reason is that retention rates are generally lower for low-aptitude personnel than for high-aptitude personnel. Thus the CAPM system demonstrated that the initial effort to make recruitment easier would actually worsen the recruitment problem in the long run.

• *Recent increases in military pay may lower reenlistment rates among some personnel.* In January 2001, the Department of Defense increased basic military pay across the board—partly to increase overall retention, but also to tie subsequent increases in pay more closely to promotions rather than to the length of time spent in any one pay grade. Researchers used the CAPM system to see how this change would affect likely retention rates among Air Force personnel. As expected, and as shown in Figure 7, retention rates generally increased as a result of the pay raise. However, the retention rate for personnel eligible for retirement after the twentieth year of service decreased in some cohorts. In particular, the model showed that there would be a fairly significant decrease in retention for those who completed 22 years of service in fiscal year 2001. The reason is that personnel who enlisted before September 8, 1980, were under a different retirement plan than those who enlisted afterwards. The model showed that the increase in basic pay would raise retirement compensation enough to encourage more people who were still under the "old" retirement plan to leave the Air Force rather than to reenlist. This exercise provides a good example of how an unexpected model prediction can lead to a fuller examination of the factors that may affect a policy's desired outcome.
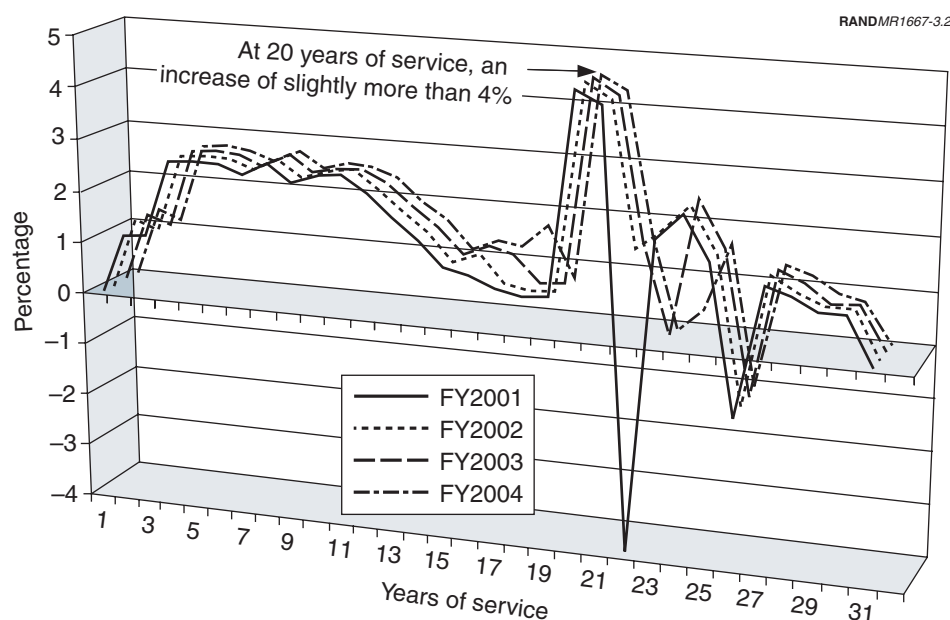

Figure 7—Reenlistment Rate Changes

CAPM Can Improve Coordination Among Personnel Policymakers

The ease with which CAPM allows analysts and decisionmakers to study the probable effects of policy changes can help coordinate efforts to improve recruitment and retention throughout the U.S. military. By improving the lives and careers of military personnel from initial recruitment through retirement, this approach will help ensure that the United States can continue to meet its peacetime and wartime commitments with a large and dedicated force.

MR-1667-AF, *Background and Theory Behind the Compensation, Accessions, and Personnel Management (CAPM) Model*, John Ausink, Jonathan Cave, Manuel Carrillo

MR-1668-AF, *Users' Guide for the Compensation, Accessions, and Personnel Management (CAPM) Model*, John Ausink, Jonathan Cave, Thomas Manacapilli, Manuel Carrillo

MR-1669-AF, *A Tutorial and Exercises for the Compensation, Accessions, and Personnel Management (CAPM) Model*, John Ausink, Albert A. Robbert

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Determining the Required Level of Noncontingency Temporary Duty for Air Force Personnel

Beginning with the Gulf War in 1990, the number of Air Force personnel deployed to contingency operations for periods of 30 consecutive days or more rose sharply, and it has not decreased substantially since then. In fact, the rates of long or hostile deployments for Air Force personnel after the Gulf War are nearly four times what they were previously. To alleviate the increased pressure of long deployments on personnel and their families, the Air Force initiated a policy after the Gulf War to limit temporary duty (TDY) away from home to 120 days in a one-year period. These 120 days encompass both contingency operations and the noncontingency operations that include activities associated with normal Air Force peacetime operations as well as individual and unit training to support readiness.

Because noncontingency duty is critical to maintaining skills in some specialties, the Air Force must manage the competing demands of contingency and noncontingency operations effectively. To do so, it must establish the level of TDY required for normal peacetime operations and use that level to determine how much time is available for contingency operations within the 120-day limit. PAF researchers analyzed data from Air Force personnel and financial reporting systems to estimate levels of noncontingency TDY. They found that TDY records are reasonably accurate in the aggregate—capturing 93 percent of total TDY days—but that records for individuals may contain substantial inaccuracies. After adjusting for inaccuracies, the researchers concluded that current levels of noncontingency TDY are close to, and sometimes exceed, the maximum possible under the 120-day limit on total TDY. In light of their findings, they recommend that the Air Force consider alternative methods to reducing the burden of contingency operations.

Current TDY Records Are Not Always Accurate

There is no centralized system designed to collect and analyze TDY data, so an office at the Air Force Personnel Center collects data from personnel and financial reporting systems and enters it into the TDY History File. Due to errors in the reporting and tabulating systems, there are some inaccuracies in this

record. On average, the TDY History File accurately captured the total number of TDY trips for 79 percent of Air Force personnel. For contingency TDY trips alone, the TDY History File was accurate for 89 percent of the individuals, and for noncontingency trips alone, it was correct for about 76 percent. In all three cases, the accuracy varied by occupation: the record was more accurate for those in personnel than for aircrews and maintenance. When in error, data on contingency trips were almost always underreported, and individual records could reflect undercounts of 30 days or more for contingency TDY. Omissions and incorrect categorizations were the sources of error in the data.

120-Day Limit on Total TDY May Be Unrealistic Given Noncontingency Needs

After identifying the patterns of error in the TDY History File, the researchers developed a model to estimate actual TDY levels more accurately, and they interviewed squadron commanders to identify the required levels of noncontingency TDY. Table 2 shows the adjusted average TDY days available for aircrews, maintenance, personnel, and security. Given that contingency deployments are normally 90 days in duration, most personnel would be unable to complete required noncontingency TDY plus a 90-day period of contingency duty and remain within the 120-day limit.

Table 2—Adjusted Average TDY Days Available for Contingencies

	Aircrews	Maintenance	Personnel	Security	Total
Enlisted	47[a]	96	98	78[a]	92
Officer	60[a]	89[a]	93[b]	88[a]	64

[a]Less than 90 days available for contingencies.
[b]Slightly more than 90 days available for contingencies.

Other Methods May Be Needed to Reduce the Burden of Increased Contingency Duty

When individuals perform all the noncontingency duty required for normal Air Force operations, the baseline TDY requirements vary from three to ten weeks, depending on the occupation and rank of the individual. With the limit of 120 total TDY days per year, aircrews can support 60 to 75 days of contin-

gency operations per year; and individuals in maintenance, personnel, and security can support as many as 90 days of contingency duty annually. RAND recommends that the Air Force consider alternatives to reducing the burden of increased contingency TDY. As a short-term measure, the Air Force could change the limit to 140 days of TDY out of a 450-day window. Long-term measures could include spreading the burden of TDY more evenly over the force through modifications in assignment policies or changing manning policies to shift larger numbers of personnel into the specialties that bear the greatest burden from contingency operations.

DB-367-AF, *What Is the Required Level of Noncontingency Temporary Duty for Air Force Personnel?* Lawrence M. Hanser, Maren Leed, Marc N. Elliott

Estimating the Operational Training Needs of Air Force Fighter Squadrons

To maintain U.S. combat readiness, Air Force fighter pilots must receive an adequate amount of operational training during peacetime. Less-experienced pilots fly training sorties under the supervision of senior pilots in order to acquire the variety of skills they need for combat operations. In recent years, the reduction in the number of fighter squadrons in the force structure, the loss of experienced pilots due to retirement and attrition, and the reduction in funding for training sorties has made it difficult for the Air Force to absorb new pilots in a timely way. This problem has resulted in an overall decline in the experience level of fighter squadrons.

As part of ongoing research on fighter pilot training, PAF has developed mathematical models that enable analysts to predict future operational training needs for fighter squadrons. PAF's approach goes beyond the existing method used by the Air Force (the Ready Aircrew Program) in three respects: (1) It takes into account the need for flight leads or instructor pilots to provide in-flight supervision of wingmen, (2) it reflects skills that underlie mission capabilities, and (3) it allows analysts to impose sortie requirements other than those for operational training on a squadron (for example, sorties for deployments). Different versions of the models exist for A/OA-10, F-16CG, F-16CJ, F-15C/D, and F-15E squadrons.

- *An optimization model calculates the minimum number of sorties needed to train a given fighter squadron.* Analysts specify the numbers of aircrew members in different positions (and with distinct capabilities) within a squadron and their levels of experience. Recognizing the underlying skills and the variety of sorties where those skills can be learned and practiced, the model calculates how many sorties must be flown per half-year to provide all crew members with adequate training. Analysts can use this model to plan future training needs and to examine how different manning configurations may raise or lower sortie requirements.

- *A simpler "repro" model reproduces selected results from the optimization model and shows how suboptimal conditions would affect pilot absorption.* For example, analysts can examine how reduced sorties, overmanning, and undermanning would affect the time it takes newcomers to acquire adequate experience and skills.

PAF is using these models for further research such as exploring how organizational changes or greater use of flight simulators would affect training requirements. These efforts will help the Air Force identify effective options to improve its absorption of new fighter pilots.

MR-1701-AF, *Models of Operational Training in Fighter Squadrons,*
James H. Bigelow, William W. Taylor, S. Craig Moore, Brent Thomas

Assessing the Validity of Uncertain Models

Military planners and other decisionmakers often use mathematical models to simulate real-world situations for purposes such as strategic planning, needs assessment, and testing new warfighting capabilities and concepts. These models must be validated to ensure that they are an adequate representation of the real-world situation for the purposes at hand. Model validation is relatively straightforward in cases where a model is based on settled theories and reliable data. However, planners often face circumstances in which the validity of a model or its data is uncertain, even massively uncertain.

PAF has developed a set of concepts that will improve analysts' ability to deal with uncertain models and data. Key principles include the following:

- *Models should be comprehensible and explainable to subject-matter experts.* One way to help validate an uncertain model is to make sure that its structure and findings are explainable in real-world terms. This goal can be accomplished by developing sound, credible, coherent, and insightful stories to illustrate a model or findings. Such stories will explain the logical relations between parts of the model, such as cause-and-effect mechanisms. Analysts should develop several stories at different levels of detail to explain the model to both fellow analysts and high-level decisionmakers

- *Models should deal effectively with uncertainty.* Analysts typically seek to remove uncertainty by making assumptions about aspects of a model that are otherwise unknown. A more valid approach is to incorporate uncertainty within a model. New methods such as multiresolution, multiperspective modeling (MRMPM) and exploratory analysis can help accomplish this goal. MRMPM uses a family of models and games to approach complex problems from different points of view. This method allows analysts to cross-calibrate models that have differing resolutions, sources of data, and perspectives. Exploratory analysis exercises a model across a range of circumstances and assumptions that represent relevant uncertainties. Such analysis treats the uncertainties simultaneously rather than one at a time. This approach allows analysts to assess the robustness of conclusions to uncertain inputs.

- *The concept of validation should be broadened to include appropriate qualifiers.* Some models are valid for limited applications even if they cannot be applied reliably under all conditions. Under current criteria, these models

would not be recognized as valid. Analysts should be able to use qualifiers such as "valid for exploratory analysis" or "valid, subject to the principal assumptions underlying the model, for exploratory analysis" when characterizing a model's validity.

MR-1750-AF, *Implications for Model Validation of Multiresolution, Multiperspective Modeling (MRMPM) and Exploratory Analysis*, James H. Bigelow, Paul K. Davis

Publications

MR-1231-AF, *Future Roles of U.S. Nuclear Forces: Implications for U.S. Strategy*, Glenn C. Buchan, David Matonick, Calvin Shipbaugh, Richard Mesic.

Since the end of the Cold War, the United States has been reexamining its basic assumptions about foreign policy and instruments of national security policy. The authors examined the possible roles of nuclear weapons in contemporary U.S. national security policy. U.S. nuclear forces are only somewhat reduced from the level the nation has maintained for decades. The United States has a range of nuclear strategies and postures from which to choose, including abolition of U.S. nuclear weapons, aggressive reductions and "dealerting," "business as usual, only smaller," more aggressive nuclear posture, and nuclear emphasis. For most foreseeable combat situations, advanced conventional weapons are probably sufficiently effective if there are enough of them and they are used properly. However, if other options are inadequate and the stakes are high enough, nuclear weapons could give the United States a decisive advantage. Nuclear weapons remain the final guarantor of U.S. security, and the United States might wish to retain the traditional threat of nuclear retaliation to deter threats to its national existence. At the same time, it should have the operational flexibility to use a modest number of nuclear weapons if the need were overwhelming and other options were inadequate. Training exercises should include use of nuclear weapons. Any nuclear strategy the United States chooses will require a different set of nuclear forces and operations practices than it has now.

MR-1402-AF, *Optimal Commercial Satellite Leasing Strategies*, Michael G. Mattock.

The Department of Defense needs far more satellite communications capacity than it owns and thus must lease satellite communications services. Communications planners can use the "rule of thumb" set forth in this study to help make efficient satellite leasing decisions in the face of uncertain demand for satellite services. It is a simple, graphical technique. Extensions to the basic model show how price uncertainty and the ability to salvage unused capacity change the appropriate amount of capacity to lease. A multiple-period version of the basic model shows how planners can consider the tradeoffs between long- and short-term leases when demand grows over time.

MR-1506-AF, *The Peacetime Tempo of Air Mobility Operations: Meeting Demand and Maintaining Readiness*, Brian G. Chow.

The dual objectives of U.S. peacetime air mobility operations have long been to meet peacetime demand and to maintain wartime readiness. The 9/11 attacks and subsequent U.S. responses have reinforced both goals. Questions have arisen, however, on whether these objectives are being adequately met in light of the reduced resources that have characterized the post-Cold War period. Accordingly, the author compares the peacetime tempo of air mobility operations during the Cold War with that of the post-Cold War era. He found that the Air Mobility Command (AMC) faces problems that hinder its ability to conduct its operations cost-effectively. For example, during FY 2000 and FY 2001, the copilots of all key AMC airlifters and tankers encountered a flying-hour shortage for meeting their training requirements. This shortage will likely recur from time to time following the culmination of Operation Enduring Freedom. Moreover, during the 1980s and the 1990s, all key AMC airlifters had an increasing number of pilots per flight, leading to a decline in training time spent actually piloting as opposed to merely observing. Moreover, AMC was found to be recouping a decreasing share of its training and operating expenses and to be flying a large number of nonpaying passengers. The author offers measures that AMC can take to alleviate its recurring flying-hour shortage and address its declining revenue base and other problems. For example, adding a capability for quickly and reversibly converting AMC aircraft from cargo and fuel carriers into dedicated passenger carriers would increase AMC's flexibility in meeting fluctuating demand.

MR-1512-AF, *Protecting the Military Utility of U.S. Space Systems,* Bob Preston, Rosalind Lewis, David Frelinger, Alexander Hou.

If attacks on U.S. space systems during crisis or conflict are likely, what form might they take and how should Air Force leaders prepare? This study examines possible attacks from the viewpoint of an opponent facing current and projected U.S. forces in military conflict. The authors focus on electronic attacks on satellite communications and navigation and the consequences on Air Force operations. They review ways to detect and respond to attacks and to reduce vulnerability and mitigate consequences. (Restricted distribution, not for public release.)

MR-1570-AF, *Motivated Metamodels: Synthesis of Cause-Effect Reasoning and Statistical Metamodeling*, Paul K. Davis, James H. Bigelow.

A metamodel is a relatively simple model that approximates the behavior of one that is more complex. A common and superficially attractive way to develop a metamodel is to generate large-model data and use off-the-shelf statistical methods without attempting to understand the model's internal workings. The authors describe research illuminating why it can be important to improve the quality of such metamodels by using even modest knowledge of cause-effect relationships to help structure them. These "motivated metamodels" may convey an understandable, if only approximate, story—i.e., an explanation. Further, even if they provide little or no improvements to average goodness of fit, motivated metamodels can be much better for supporting decisions. For example, if the modeled system could fail if *any* of several critical components fail, then motivated models can build in the requisite nonlinearity, whereas naïve metamodels are misleading. Naïve metamodeling may also be misleading about the relative "importance" of inputs, thereby skewing resource-allocation decisions. Motivated metamodels can greatly mitigate such problems. The work contributes to the emerging understanding of multiresolution, multiperspective modeling (MRMPM), as well as providing an interdisciplinary view of how to combine virtues of statistical methodology with virtues of theory-based work.

MR-1584-AF, *Assessing Selected Space-Based Infrared System-High (SBIRS-High) System Risks*, Timothy Bonds, James Bonomo, John Graser, Jon Grossman, Joel Kvitky, Rosalyn Lewis, Manuel Cohen, Gary McLeod, Richard Mesic, David Vaughan, Robert Leonard, Mel Eisman, Lionel Galway.

This report summarizes the findings from a RAND analysis conducted for the Air Force Cost Analysis Agency as part of that agency's independent cost analysis of the Space-Based Infrared System-High. The study team assessed risk factors, technical challenges in completing the system development, and the adequacy of the contractors' risk-management approaches. (Restricted distribution, not for public release.)

MR-1603-AF, *Interoperability of U.S. and NATO Allied Air Forces: Supporting Data and Case Studies*, Eric Larson, Gustav Lindstrom, Myron Hura, Ken Gardiner, Jim Keffer, Bill Little.

The United States conducts air operations with NATO allies, including non-NATO countries. The objective of this background research for a larger study, *Interoperability: A Continuing Challenge in Coalition Air Operations*, is twofold:

first, to help the U.S. Air Force identify potential interoperability problems that may arise in coalition air operations involving the United States and its NATO allies, as well as non-NATO countries, over the next decade and, second, to suggest solution directions to mitigate those problems. The study focus is on command, control, communications, intelligence, surveillance, and reconnaissance (C3ISR) systems and out-of-NATO-area operations. The authors present a data-based historical overview of the U.S. experience in coalition operations with NATO allies up to 1999, and they seek to provide a deeper understanding of interoperability through the answers to several key questions: For what missions is interoperability required? With which NATO allies is interoperability required? For what capabilities and services is interoperability required? Detailed case-study analyses of coalition operations in Southwest Asia, Bosnia, Somalia, and Rwanda identify key interoperability challenges and workarounds (short-term solutions) at the strategic, operational, tactical, and technological levels. The case studies also provide relevant lessons for meeting these challenges and improving the interoperability of U.S. and NATO air and C3ISR capabilities.

MR-1611-AF, *Effective Treatment of Logistics Resource Issues in the Air Force Planning, Programming, and Budgeting System (PPBS) Process*, Frank Camm, Leslie Lewis.

The Air Force's logistics supply chain involves the participation of many organizations, inside and outside the Air Force, to serve a variety of users with differing needs. The Air Force uses the Planning, Programming, and Budgeting System (PPBS) to fund all elements of the supply chain at levels that give its users appropriate levels of service. The PPBS process has a great deal of difficulty doing this well. Important changes in the Air Force PPBS, financial management, and logistics management processes over the past 15 years have made the task even more difficult. The authors propose several changes in strategy and policy designed to help the Air Force manage and fund its logistics supply chain in a more integrated manner—a manner that can set goals relevant to its customers and use closed-loop accountability systems to manage the supply chain, end-to-end, against these goals. Full implementation of the proposed changes would challenge Air Force organizational culture. The authors identify specific cultural barriers that the Air Force must address to effectively pursue the proposed changes.

MR-1613-AF, *The Dynamics of Growth in Worldwide Satellite Communications Capacity*, Michael G. Mattock.

The Department of Defense (DoD) cannot afford to own all the satellite communications capacity it might require in all areas of the world. DoD planners estimate that they will need to provide about 16 Gigabits per second of bandwidth by 2010 to effectively support a joint-service operation. However, given current procurement plans, the DoD will own only one-eighth of this projected desired capacity. Therefore, for the foreseeable future, the DoD must buy at least some of its communications capacity from commercial vendors. An ability to understand what drives growth in worldwide satellite capacity and to predict capacity would be useful to military communications planners in making advance decisions to purchase and lease communications capacity in various parts of the world. The author shows that there is a strong relationship between growth in total satellite communications capacity and economic growth, as measured by Gross Domestic Product. Adjustment to change is quite rapid; if there is an imbalance in the long-run equilibrium between supply and demand, on average 25 percent of the adjustment is made within one year, although there is some regional variation. The analysis indicates that the market can adjust swiftly to a surge in demand, and thus there may be little need to buy satellite capacity in advance simply to ensure that capacity will be there if needed.

MR-1614, *Supporting Expeditionary Aerospace Forces: Engine Maintenance Systems Evaluation (EnMasse)—A User's Guide*, Mahyar A. Amouzegar, Lionel A. Galway.

As the U.S. Air Force evolves into an Expeditionary Aerospace Force, its methods for maintaining its aircraft must evolve as well. The authors have developed a simulation tool, the Engine Maintenance System Evaluation (EnMasse), to assess the effect of different policies, such as centralized maintenance, on jet engine intermediate maintenance (JEIM) operations. This user's guide to EnMasse describes the workings of the various processes (module shop, test cell, etc.) in the simulation model. The model allows the user to track the engine operation and maintenance process from the flightline (in deployed or home locations) through the various maintenance shops and back. The guide delineates essential components of EnMasse that the user might employ or modify to build a model for various choices of engine types and maintenance policies.

MR-1625-AF, *Reconfiguring Footprint to Speed Expeditionary Aerospace Forces Deployment*, Lionel A. Galway, Mahyar A. Amouzegar, Richard J. Hillestad, Don Snyder.

Studies examining support requirements for expeditionary operations have determined that moving all the materiel needed within the 48-hour goal is infeasible at present. As a result, there has been a call for "footprint reduction"—reducing the amount of materiel and personnel deployed. Some attention has been given to reducing the size of equipment (smaller avionics testers, lighter shelters and billeting equipment), but such reductions may not be feasible in all areas. Researchers have also examined such alternatives as time-phasing the deployment of support and relocating some equipment to places other than forward operating locations. This study develops an analysis framework—footprint configuration—to assist in devising and evaluating such comprehensive strategies. It also attempts to define footprint and to establish a way to monitor its reduction. Because the goal of the expeditionary concept is to be ready to deploy quickly to bases that might be unprepared, generic equipment lists are needed that are not tailored to specific bases but that can be used as templates for deployment packages. Such lists could serve as a starting point for tailoring for deliberate planning and as a basis for strategic support.

MR-1641-AF, *Aging Aircraft: USAF Workload and Material Consumption Life Cycle Patterns*, Raymond A. Pyles.

The U.S. Air Force currently plans to retain aircraft fleets for unprecedentedly long service lives, which may be as long as 80 years. The safety, aircraft availability, and cost implications of that fleet-retention policy are unknown. This study is part of a project to improve the Air Force's ability to foresee those implications and identify actions that will mitigate or avoid some of the more severe consequences. Using data from past RAND and industry reports and from various Air Force instructions and maintenance databases, and a regression analysis, the study measures how the ages of aircraft fleets relate to maintenance and modification workloads and material consumption. It provides the foundation for future estimates of the effects of those activities on maintenance-resource requirements, aircraft availability, and annual operating cost.

Maintenance workloads and material consumption generally exhibited late-life growth as aircraft aged, but the rate of that growth depended on both the aircraft's flyaway cost and the workload category. For example, long-term, late-life growth was found in all base- and depot-level maintenance workloads and

material-consumption categories, except phased and/or isochronal inspections, per-flying-hour contractor logistics support, and depot modification work-loads. Where data were available, all workload and cost categories were affected by differences across commands and early-life transitional events (e.g., break-in periods, early failures). Computational approaches are being developed to fore-cast aircraft availability from aggregate maintenance-workload data. Future work may address how planners can exploit the equations given here to address near-term budget and resource-requirement forecasts.

MR-1649-AF, *Mastering the Ultimate High Ground: Next Steps in the Military Uses of Space*, Benjamin S. Lambeth.

This study assesses the military space challenges that face the Air Force and the nation in light of the findings and recommendations of the congressionally mandated Space Commission, released in January 2001. After reviewing the main milestones in the Air Force's involvement in space since its creation as an independent service in 1947, the author examines the circumstances that occasioned the Space Commission's creation, as well as the conceptual and organizational roadblocks that have impeded a more rapid growth of U.S. military space capability. He concludes that the Air Force faces five basic challenges with respect to space: continuing the operational integration of space with the three terrestrial warfighting mediums while ensuring the organizational differentiation of space from Air Force air, effectively wielding its newly granted military space executive-agent status, realizing a transparent DoD-wide budget category for space, showing progress toward fielding a meaningful space control capability while decoupling that progress from any perceived taint of force-application involvement, and making further progress toward developing and nurturing a cadre of skilled space professionals within the Air Force.

MR-1650-AF, *Establishing and Sustaining Constellations of Distributed Satellites: A Space-Based Radar Example*, Bob Preston, Mel Eisman, Michael Brown.

If a single satellite cannot provide adequate service, multiple satellites may cooperate in a constellation of orbits to extend reach in time, space, or both to provide the service. For example, two weather satellites can provide morning and afternoon observations. Navigation satellites can provide enough reference points for precise location. A space system's function can be distributed across multiple satellites in different orbital positions to obtain performance not possible with a single satellite. This notion of distributed satellites could extend further if a satellite in an orbital location were replaced with multiple, closely cooperating satellites. This study explores the potential advantages and disad-

vantages of distributed satellite architectures. For context, the illustrative application is radar surveillance of moving targets on the ground. (Restricted distribution, not for public release.)

MR-1667-AF/OSD, *Background and Theory Behind the Compensation, Accessions, and Personnel Management (CAPM) Model*, John Ausink, Jonathan Cave, Manuel Carrillo.

The Compensation, Accessions, and Personnel Management (CAPM) model is a software package that enables analysts to study the potential effects of personnel policy changes on future enlisted inventories in the military services. The software is Excel based and uses several modules written in Visual Basic for Applications. The authors provide theoretical background for the reenlistment module of the software. They begin with some general information about econometric models of retention behavior and then describe the Annualized Cost of Leaving (ACOL) and the ACOL 2 models, which are the basis for the adjustment of retention rates in CAPM. Calculation of annualized cost of leaving values, their use in projecting inventories, and examples of CAPM outputs for Air Force enlisted personnel are also discussed. To provide some perspective on the general problem of modeling retention behavior in the military, the authors examine the Dynamic Retention Model (DRM), an intuitively satisfying but computationally difficult model that was developed at RAND in the late 1970s. This report seeks to improve understanding of some modeling fundamentals and assist in future improvements of the CAPM model.

MR-1668-AF/OSD, *Users' Guide for the Compensation, Accessions, and Personnel Management (CAPM) Model*, John Ausink, Jonathan Cave, Thomas Manacapilli, Manuel Carrillo.

The military has long planning and operational horizons, vast amounts of data that affect the decisionmaking process, and customarily short tours of duty for decisionmaking personnel. The Compensation, Accessions, and Personnel Management (CAPM) system was designed to merge data and tools for analysis and to assist coordination of policy efforts. It is an Excel-based integrated decision support system using several modules written in Visual Basic for Applications. It combines data access, policy projection, and supporting analysis tools in a flexible, integrated platform. The system consists of several levels: a graphic user interface, models, databases, a collection of miscellaneous software tools, and a hardware setup. This report provides a general overview of the CAPM system, with a conceptual discussion of the model design and

approach. It describes the CAPM user interface and discusses the various notebooks used in the software, the settings and options available when using them, and how to inspect the output of model runs. It also provides a detailed description of the CAPM functions that can be manipulated when studying policy changes.

MR-1669-AF/OSD, *A Tutorial and Exercises for the Compensation, Accessions, and Personnel Management (CAPM) Model*, John Ausink, Albert A. Robbert.

The Compensation, Accessions, and Personnel Management (CAPM) system, designed to merge data and tools for analysis and to assist coordination of policy efforts, is described in the above abstract for MR-1668-AF/OSD. This document demonstrates the model's capabilities in tutorial format and shows how CAPM can be used to model some prototypical policy issues. Its primary purpose is to help users explore the model's capabilities and gain confidence in manipulating its parameters.

MR-1701-AF, *Models of Operational Training in Fighter Squadrons*, James H. Bigelow, William W. Taylor, S. Craig Moore, Brent Thomas.

Operational squadrons in the U.S. Air Force train to accomplish two objectives: to maintain readiness to deploy and operate in wartime, contingencies, and other engagements, and to prepare aircrew members for subsequent assignments at wings, major air commands, and the Air Staff. Although some operational training is needed to achieve these objectives, it has been difficult historically to justify any specific amount of flying. This report describes a model of aircrew training in an operational fighter squadron. Users of the model, which is formulated as a linear program, specify the number of pilots by qualification in a squadron, and the model calculates the minimum number of sorties that must be flown within a certain period to provide all assigned crew members with the operational training they need. Because such models tend to be somewhat cumbersome, the authors also developed simpler and more-compact "repro" models that reproduce selected results from the linear program and that can be implemented in a spreadsheet format.

MR-1706-AF, *A Framework for Modernization Within the United States Air Force*, Glenn A. Kent, David A. Ochmanek.

The authors lay out a framework for modernizing that the Air Force can use to develop new operational concepts in the context of joint-service requirements, to organize analyses for assessing capabilities, and to effectively advocate Air

Force programs to decisionmakers in the Office of the Secretary of Defense and Congress. The study builds on earlier work on a strategies-to-tasks framework, concept development, and up-front planning. The broad conceptual framework promotes innovation and modernization of Air Force capabilities and is consistent with the chief of staff's emphasis that capabilities be developed and fielded in a timely manner. The framework offers a clearly defined set of relevant terms applicable at several levels of operation; it generically identifies the principal actors within the Air Force who are guiding and promoting innovation; it lays out a process governing the interactions among these principal actors; and it lists operational capabilities, derived from the defense strategy and from joint-service employment concepts, that could be used to organize modernization efforts.

MR-1738-AF, *Military Operations Against Terrorist Groups Abroad: Implications for the United States Air Force*, David Ochmanek.

The imperative to monitor, suppress, attack, and ultimately eradicate international terrorist groups seeking to strike the United States, its citizens, its interests, and its allies is prompting significant changes in the demands placed on the United States armed forces. U.S. forces will often be called upon to assist foreign governments that wish to eradicate terrorist groups on their territory but lack the capabilities to do so on their own. In such cases, U.S. forces can provide training and equipment to strengthen the capabilities and will of host-government forces, disrupt terrorist activities, find and capture or kill terrorists, help to alienate terrorists from the populace, gather intelligence about terrorist networks and activities around the world, and protect friendly forces and bases. In effective counterterrorist activities, the host nation will play the leading role in hunting down terrorists; the terrorists will be under relentless pressure and forced to react to government-initiated operations; operations will depend on accurate information about the terrorists or insurgents; and the host government will win the support of the populace, depriving the terrorists of support. Effective concepts of execution for locating and engaging terrorists might employ wide-area surveillance sensors, high-resolution sensors, dynamic engagement control, and precision-guided weapons with small warheads.

MR-1744-AF, *NATO's Eastern Agenda in a New Strategic Era*, F. Stephen Larrabee.

Now that the Prague summit is concluded, NATO faces a number of new challenges in its Eastern agenda. First, it must ensure that the democratic transitions in Central and Eastern Europe are consolidated and that there is no

backsliding. These countries must modernize their military forces and make them interoperable with those of NATO. Second, NATO must remain engaged in and ensure the security of the Baltic states. The problem of Kaliningrad should be addressed and the enclave stabilized. Third, NATO needs to develop a post-enlargement strategy for Ukraine to support the country's continued democratic evolution and integration into Euro-Atlantic structures. Fourth, Russia must be incorporated into a broader European and Euro-Atlantic security framework. Finally, NATO needs to develop a coherent strategy toward the Caucasus and Central Asia. The Partnership for Peace can provide the framework for developing relations with these countries. Other U.S. and NATO policies can encourage greater openness, reform, and democratic practices. Moreover, these challenges must be addressed in a new strategic context. In the post-Prague period, the key issue is NATO's transformation and its strategic purpose: What should its missions and strategic rationale be?

MR-1746-AF, *The Counterterror Coalitions: Cooperation with Europe, NATO, and the European Union*, Nora Bensahel.

The long-term success of the counterterror campaign will depend on concerted cooperation from European states, but a key question is the extent to which that cooperation should be pursued through European multilateral institutions. NATO has not yet reoriented itself to challenge terrorism, although it has adopted a number of initiatives to improve its counterterror capabilities. The European Union, limited in its military and intelligence capabilities, has taken a number of initiatives in justice and home affairs. This study argues that the United States should pursue military and intelligence cooperation on a bilateral basis, and it should increasingly pursue financial and law enforcement cooperation on a multilateral basis. The United States might adopt a more multilateral approach as cooperation within the European Union increases. Multilateral cooperation with a strengthening European Union would enhance the ability of states on both sides of the Atlantic to prevent terrorism and prosecute those involved in terrorist activities.

MR-1750-PAF, *Implications for Model Validation of Multiresolution, Multiperspective Modeling (MRMPM) and Exploratory Analysis*, James H. Bigelow, Paul K. Davis.

The authors draw on several of their past studies to illustrate with concrete examples how multiresolution, multiperspective modeling (MRMPM) and exploratory analysis relate to model validation when the models are not solidly based in settled theory or empirical testing appropriate to the application in

question. It is argued that in such cases, the validation process might reasonably assess a model and its associated databases as "valid for exploratory analysis" or "valid, subject to the principal assumptions underlying the model, for exploratory analysis" for a particular context. A model and its data may not be fully "valid," but they may still be both useful and good in more limited ways. It is important that a model being assessed be comprehensible and explainable and that its data deal effectively with uncertainty, possibly massive uncertainty. Crucial enabling capabilities are provided by multiresolution, multiperspective modeling, including exploratory analysis as well as families of models and games. These methods are valuable for extrapolating, generalizing, and abstracting from small sets of analyses accomplished with detailed models; for top-down planning; and for providing broad, synoptic assessments of problem areas. They are also important for achieving a deep understanding of problems and communicating insights credibly to others.

DB-367-AF, *What Is the Required Level of Noncontingency Temporary Duty for Air Force Personnel?* Lawrence M. Hanser, Maren Leed, Marc N. Elliott.

Following the Gulf War, the U.S. Air Force placed a 120-days-per-year ceiling on temporary duty (TDY) both for contingency operations and noncontingency-related activities, including training courses and exercises. However, questions have arisen on the extent to which the competing demands for TDY may be adversely affecting Air Force training activities. Accordingly, the authors sought to ascertain how much noncontingency TDY the Air Force needs to maintain requisite levels of training and readiness. They compared the accuracy of current Air Force TDY data, as captured in the Air Force Personnel Center's TDY history file, with data on TDY that individuals actually performed. They also interviewed more than 40 squadron commanders to determine whether contingency operations had indeed taken a toll on noncontingency-related efforts. The authors conclude that widespread errors exist in recording TDY, with many such errors attributable to miscategorizations or to missing data. Interviews further revealed that more than half of all squadron commanders felt that noncontingency TDY levels were lower than required—critical noncontingency TDYs had been missed or postponed for reasons other than contingency operations. On the basis of these findings, the authors recommend that the Air Force's TDY tracking system be improved and that TDY for contingency operations be reduced.

DB-392-AF, *Intelligence, Surveillance, and Reconnaissance System Considerations Regarding Narcotics and Ocean Monitoring*, Sherrill Lingel, Michael Scheiern.

This study delineates four small-scale contingencies pertaining to ocean and narcotics trafficking monitoring. The authors identify scenario characteristics that require specific intelligence, surveillance, and reconnaissance (ISR) capabilities and examine necessary force sizes for narcotics and ocean surveillance scenarios. (Restricted distribution, not for public release.)

DB-398-AF, *The Effects of Advanced Materials on Airframe Operating and Support Costs*, Raj Raman, John C. Graser, Obaid Younossi.

Advanced materials—particularly polymer composites and titanium—are increasingly being used instead of aluminum in military airframe structures because of their superior strength and lighter weight. The authors considered whether airframe parts made of advanced materials cost more to maintain than parts made of aluminum. Because little is known about the operating and support costs of airframe parts after an aircraft is fielded and operational, the authors produced a methodology for forecasting these costs. They analyzed part-level maintenance data from the F/A-18 A/B/C/D and survey-based data from airframe contractors and the B-2 Program Office. In their F/A-18 part-level analysis, they concluded that maintenance is a function of part type and material type; access doors are the most expensive parts to maintain. Their findings also indicate that composite materials require more maintenance than aluminum; composite parts containing aluminum honeycomb substructures require the most maintenance. Titanium parts, by comparison, need the least maintenance. Survey-based data showed similar results, with the exception of the airframe contractor's survey data, which had mixed results for titanium parts.

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